CSCE 2020

August 12, 2020

2nd CONFERENCE ON SUSTAINABILITY IN CIVIL ENGINEERING

PROCEEDINGS BOOK

ISBN 978-969-23344-1-9

CAPITAL UNIVERSITY OF SCIENCE & TECHNOLOGY
DEPARTMENT OF CIVIL ENGINEERING

FOREWORD

Welcome to the CSCE 2020, 2nd Conference on Sustainability in Civil Engineering (CSCE'20) is going to be held by Department of Civil Engineering, Capital University of Science and Technology, Islamabad, Pakistan. The main focus of CSCE'20 is to highlight sustainability related to the field of civil engineering. It aims to provide a platform for civil engineers from academia as well as industry to share their practical experiences and different research findings in their relevant specializations. We hope all the participants experience a remarkable opportunity for the academic and industrial communities to address new challenges, share solutions and discuss future research directions. The conference accommodates several parallel sessions of different specialties, where the researchers and engineers interact and enhance their understanding of sustainability in the civil engineering dynamics.

This year, we have wonderful and renowned keynote speakers for this edition of CSCE. We have received 143 manuscripts from different countries around the world including UK, Australia, Italy, Vietnam, China, KSA and Pakistan. All papers have under gone a comprehensive and critical double-blind review process. The review committee comprised of 42 PhDs serving in industry and academia of UK, Hungry, Australia, New Zealand, Chile, Thailand, China, Malaysia, KSA, Oman and Pakistan. After the screening and review process, 68 papers are to be presented in Conference.

We are a grateful to all the reviewers and keynote speakers who have dedicated their precious time to share their expertise and experience. With this opportunity, we would also like to express our gratitude to everyone, especially all the faculty and staff at the Capital University of Science and Technology for their great support and participation.

In this regard, the participation and cooperation of all authors, presenters and participants are also acknowledged, without whom this conference would not have been possible. Last but not least, an appreciation to our advising and organizing committees whose hard work and dedication has made this day possible.

Conference Chair of CSCE'20

Dr. Majid Ali

Capital University of Science & Technology,
Islamabad, Pakistan

TECHNICAL COMMITTEE

Dr. Shunde Qin	WSP Global Inc. United Kingdom
Dr. Furqan Qamar	WSP Global Inc. United Kingdom
Dr. Hamid Mehmood	Transport Dept. Victoria, Australia
Dr. Wajiha Gulzar	Massey University, New Zealand
Dr. Mohsin Shehzad	Mott MacDonald, New Zealand
Dr. Fenyvesi Oliver	BME, Hungary
Dr. Claudio Oyarzo Vera	UCSC, Chile
Dr. Muhammad Raza Ul Mustafa	UTP, Malaysia
Dr. Teh Hee Min	UTP, Malaysia
Dr. Wesam Salah Alaloul	UTP, Malaysia
Dr. Khairunisa Binti Musthsuamy	Pahang University, Malaysia
Dr. Naveed Anwar	AIT, Thailand
Dr. Cao Mingli	DUT, China
Dr. Li Li	NW A&F University, China
Dr. Munir Ahmed	DAR Engineering, KSA
Dr. Umar Farooq	Islamic University of Madinah, KSA
Dr. Mohsin Usaman Qureshi	Sohar University, Oman
Dr. M Zia ur Rehman Hashmi	GCISC, Pakistan
Dr. Irfan Yousuf	AEDB, Pakistan
Dr. Shaukat Ali Khan	UoL, Islamabad, Pakistan
Dr. Liaqat Ali Qureshi	SCET Wah, Pakistan
Dr. Shaukat Ali Khan	Abasyn University, Peshawar, Pakistan
Dr. Ayub Elahi	UET, Taxila, Pakistan
Dr. Sher Jamal Khan	NUST, Islamabad, Pakistan
Dr. Khan Zeb Jadoon	IIU, Islamabad, Pakistan
Dr. Jawad Hussain	UET, Taxila, Pakistan
Dr. Mudassir Muneer Khan	Baha Uddin Zakariya University, Pakistan
Dr. Rao Arslan Khushnood	NUST, Islamabad, Pakistan
Dr. Muhammad Alam	Abasyn University, Peshawar, Pakistan
Dr. Hassan Ashraf	COMSATS University Wah, Pakistan
Dr. Hassan Nasir	CECOS Peshawar, Pakistan
Dr. Naveed Ahmed	UET, Peshawar, Pakistan
Dr. Malik Muneeb Abid	University of Sargodha, Pakistan
Dr. Sabahat Hassan	HITEC University Taxila, Pakistan
Dr. Naveed Ahmad (Transportation)	UET, Taxila, Pakistan
Dr. Muhammad Adil	UET, Peshawar, Pakistan
Dr. Adnan Nawaz	COMSATS University Wah, Pakistan
Dr. Faisal Javed	COMSATS University, Abbottabad, Pakistan
Dr. Fawad Najam	NUST, Islamabad, Pakistan
Dr. Tahir Mehmood	COMSATS University Wah, Pakistan
Dr. Irshad Qureshi	UET, Taxila, Pakistan
Dr. Naveed Ahmad (Geotech)	UET, Taxila, Pakistan

ADVISORY COMMITTEE

Dr. M. Mansoor Ahmed
(Vice-Chancellor CUST Islamabad)
Patron

Dr. Imtiaz Ahmed Taj
(Dean Faculty of Engineering)
General Advisor

Dr. Ishtiaq Hassan
(Head of Civil Engineering Department)
Principle Advisor

ORGANIZING COMMITTEE

Dr. Majid Ali
Chair

Dr. Syed Shujaa Safdar Gardezi
Co – Chair

Engr. Abdul Qadeer
Conference Secretary – I

Engr. Umair Ahmed
Conference Secretary –II

KEYNOTE SPEAKERS

Dr. Qaisar Ali *VC UET Peshawar, Pakistan*	***The impact of Civil Engineering on Humanity***
Dr. Shahid Nasir *Director FE (Pvt.) Ltd,* *Islamabad, Pakistan*	***Current Trends of Bridge Engineering in Pakistan***
Dr. M. Waris Ali Khan *P.E. PMP Universiti Malaysia Pahang, Malaysia*	***Towards Green Procurement Practices in Infrastructure Construction Projects: A Sustainable Approach to Manage Eco-Sensitive Projects in Pakistan***
Dr. Rabee Shamass *London South Bank University, UK*	***The Use of Basalt Fibers Reinforced Polymers BFRP in Concrete Structures***
Dr. Irfan Yousuf *NEPRA, Islamabad, Pakistan*	***Civil Engineering Vigilance in COVID'19 Era***
Dr. Habib ur Rehman *UET, Lahore*	***Monitoring and Modelling of Groundwater Recharge Through Recharging Well***

TABLE OF CONTENTS

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

SIGNIFICANCE OF INCORPORATING STEEL FIBER AND POLYVINYL ALCOHOL FIBER IN CEMENT BASED COMPOSITES UNDER STATIC AND DYNAMIC LOAD

[a] Mehran Khan, [b] Mingli Cao
a: School of Civil Engineering, Dalian University of Technology, Dalian, Liaoning, China, drmehrankhan@mail.dlut.edu.cn
b: School of Civil Engineering, Dalian University of Technology, Dalian, Liaoning, China, minglic@dlut.edu.cn

Abstract- The single fiber reinforced concrete had improved mechanical properties than plain concrete. However, the addition of different fibers together resulted in better crack arresting performance at different scale that of individual fibers. Therefore, the steel fibers and polyvinyl alcohol (PVA) fibers are blended together to achieve the fiber bridging performance at multi scale. The inclusion of these two fibers will contribute together at their particular level and will contribute in the improvement of mechanical and dynamic properties. In this paper, the properties of steel fibers and polyvinyl alcohol fibers are studied with different length and contents to study the static and dynamic behavior of cementitious composites. For static properties, compressive strength and peak micro strain are determined; and to evaluate the dynamic behavior the curves of column top acceleration-time are considered. The addition of multi-scale fibers resulted in enhanced peak micro strain and showed longer time period under dynamic load. This indicate the positive synergy of steel and PVA fibers blend designed for improved static and dynamic properties of cementitious composites.

Keywords- Crack arresting performance, Steel fibers, Polyvinyl alcohol fibers, Static properties, Dynamic properties.

1 INTRODUCTION

The performance of fiber reinforced cementitious composites (FRCC) are influenced by many factors like base matrix characteristics, fibre size, length and mix proportion [1-3]. FRCC are developed to reduce the brittleness of plain composites and improves its crack resistance performance [4]. The dynamic behavior of cementitious composites are necessary parameter to assess the safety performance [5]. The FRCC showed improved performance in earthquake resistant structures as compared to that of plain composites (PC) [6]. Steel fibers are generally used as a basic material for improvement in toughness of FRCC [7, 8]. Also, the PVA fiber are used in FRCC because of its high strength, large elongation, higher elastic modulus and bond strength [6, 9]. The improvement in toughness as well as crack arresting mechanism of composites is observed with use of PVA fiber [6]. The fiber composite should be design for enhanced energy absorption capability under dynamic load [1]. The addition of hybrid fibers result in reducing the crack propagation and delay the crack growth in cementitious composites. Thus, the combination of steel and PVA fibers may reduce the crack growth by controlling the displacement and acceleration of composites under dynamic load. During service life of composites structure it experiences a lot of dynamic loads like seismic load, hydrodynamic pressure and wind load [10, 11]. It was found that the behaviour of composite structure under dynamic load are relatively changed than under static loading [12]. The strong dynamic load due to earthquake can damage the structures and cause a huge loss in earthquake prone areas. The PC are susceptible to failure under the dynamic load due to its brittle behavior [6]. Hence, it is essential to make a FRCC with superior characteristic to resist dynamic load that may be suitable for area susceptible to earthquake.

Hybrid fiber reinforced composite is a compound material and many parameters effect its cracking mechanism like mixing regime, mix composition and basic raw material etc [13]. There are three basic stages during crack process in cement-based material, i.e. initial cracking stage, crack extension stage and final stage when crack open. It is obvious that there are always some pre-existing crack available in cementitious composites. When the load is applied, the existence of these cracks will cause the stress redistribution in cementitious composites and will result in development of cracks in CSH and cement paste layer. By further increment in applied load, the crack will start to extend and step into crack extension stage in cement based material. At this stage, the PVA fiber will come across the crack and provide the bridging law in fiber composites. The bridging law of PVA fiber will result in fiber pull out or fiber fracture ultimately consume more energy.

In the meanwhile, further addition of load will expand the crack and at the same time, the steel fiber start to act as bridge between the cracks and does not allow the crack to propagate in cementitious material. This bridging law will delay the crack growth and increase the crack propagation pathway eventually result in improved performance of hybrid fiber cementitious composites under dynamic load. The addition of single type fiber in composites will provide crack resistance at one scale, but the inclusion of hybrid fibers will provide the bridging law at different scale as per their size limitations. Therefore, to achieve the better performance under static and dynamic load the use of hybrid fiber are more effective than that of single fiber in cement based composites.

To the best of author's knowledge no study is reported on dynamic mechanical properties of single degree of freedom specimen prepared by steel fiber-PVA fiber reinforced composites under hydraulic shaking table. However, researchers focused the dynamic behavior of hybrid fiber reinforced composites with steel bars; but this study is an initiative to study the behavior of hybrid fiber reinforced composites without steel bars. Therefore, this study explore the effectiveness of dynamic response of single degree of freedom steel fiber-PVA fiber reinforced composites. The cube compressive strength and peak strain are evaluated for static parameters; and for dynamic behavior, the column top-acceleration time curves are recorded.

2 EXPERIMENTAL PROCEDURES

The cement, quartz sand, super plasticizer, steel fiber and PVA fiber are used. The physical parameters of quartz sand, steel fiber and PVA fiber are presented in Table 1.A total of four mix proportion was considered and named as 2SF/13mm, 1.5SF/13mm + 0.5PVA/6mm, 2SF/35mm and 1.5SF/35mm + 0.5PVA/12mm. The SF and PVA represents the steel and PVA fiber, respectively; and 2, 1.5 and 0.5 denotes the percentage of fibers. The short-steel fibers (13mm), short-PVA fibers (6mm), long steel fibers (35mm) and long PVA fibers (12 mm) were used. The mixing procedure is shown in Figure 1, respectively. After uniform mixing, the moulds of cubes and columns with fresh matrix were filled and vibrating table was used for compaction. Finally, the cubes and columns were demoulded and kept at 20℃ for 28 days.

Table 1- Physical parameters of raw materials

Raw materials	**Density (g / cm^3)**	**Physical Parameters**	**Mechanical Properties**
Quartz sand	2.65	Fineness modulus (2.51)	Moh's hardness = 7.0
Steel fiber	7.8	Length (13 mm and 35 mm)	Tensile strength ≥ 2 GPa
PVA fiber	1.29	Length (6 and 12 mm)	Tensile strength ≥ 1.1 GPa

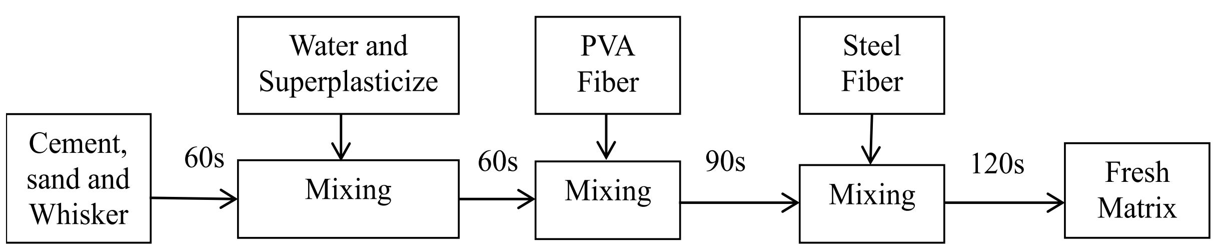


Figure 1: Mixing procedure

3 RESEARCH METHODOLOGY

The WAW / 600D universal testing machine (UTM) was used to test the FRCC cube specimen under for compressive load as per ASTM standard C39 [14]. The single degree of freedom SST-100 hydraulic shaker as shown in Figure 2 (a) was used to evaluate the dynamic behavior of FRCC. The dynamic signal acquisition system was used to calculate the dynamic signal measurement and analysis. The maximum force and acceleration was 100 KN and 1 g, respectively. The size of shaking table was 2000 mm × 2000 mm × 200 mm. The real time test data was determined, which include column top acceleration obtained from acceleration sensor as shown in Figure 2 (b).

4 Results And Discussion

4.1 Static properties

The compressive strength and strain at peak are shown in Figure 3. The compressive strength for short length fiber composites of SF/13mm and 1.5SF/13mm were 81.75 MPa and 62.15 MPa, respectively. However, the long length fiber addition in composites of 2SF/35mm and 1.5SF/35mm + 0.5PVA/12mm were 79.55 MPa and 70.70 MPa, respectively. The incorporation of PVA fibers resulted in decrease trend for both groups, i.e. short length fibers composites and long length fiber composites. It is obvious that addition of fibers may reduce the compressive strength but it result in increased strain capacity of composites as evident from Figure 3 (b). The peak strain of hybrid fibers composites was increased with addition of steel and PVA fibers together than that of single length steel fiber. However, the better improvement was observed in peak strain with addition of long hybrid fibers as compared to that of short length hybrid fibers. The higher stiffness and higher modulus of steel fibers with 2% content resulted in greater compressive strength. On the other hand, the hybrid fiber composites with steel and PVA fibers resulted in low compressive strength. This is because inclusion of PVA fibers in composites produced new interfaces, which are the basis for low compressive strength. Similar results are also stated by Cao, et al. [15]. In addition, the blend of steel and PVA fibers together showed positive synergy and increased the peak micro strain of hybrid fiber composites that that of single fiber composites.

a) b)

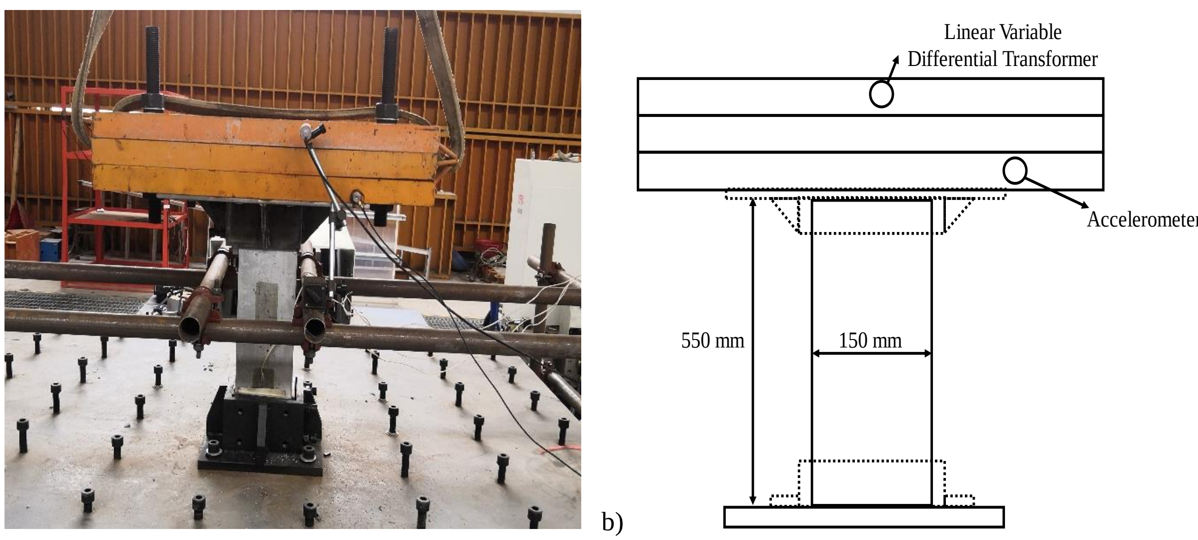
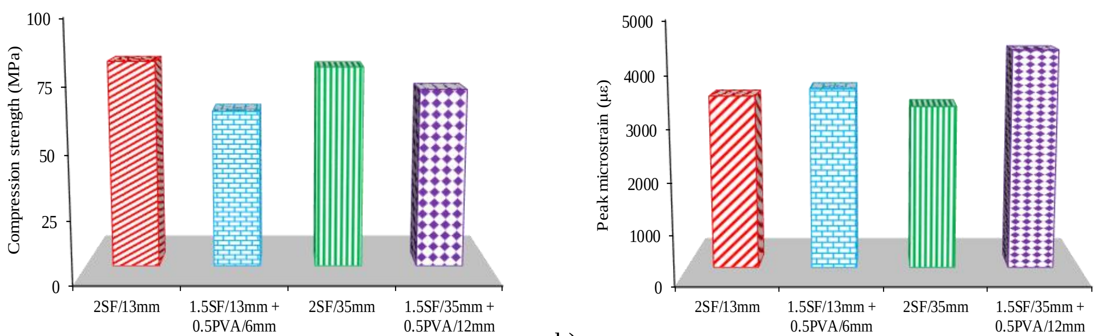


Figure 2: Test setup, a. (a) column under dynamic load, and b. schematic diagram



a) b)

Figure 3: Static properties, a. compressive strength, and b. strain at peak

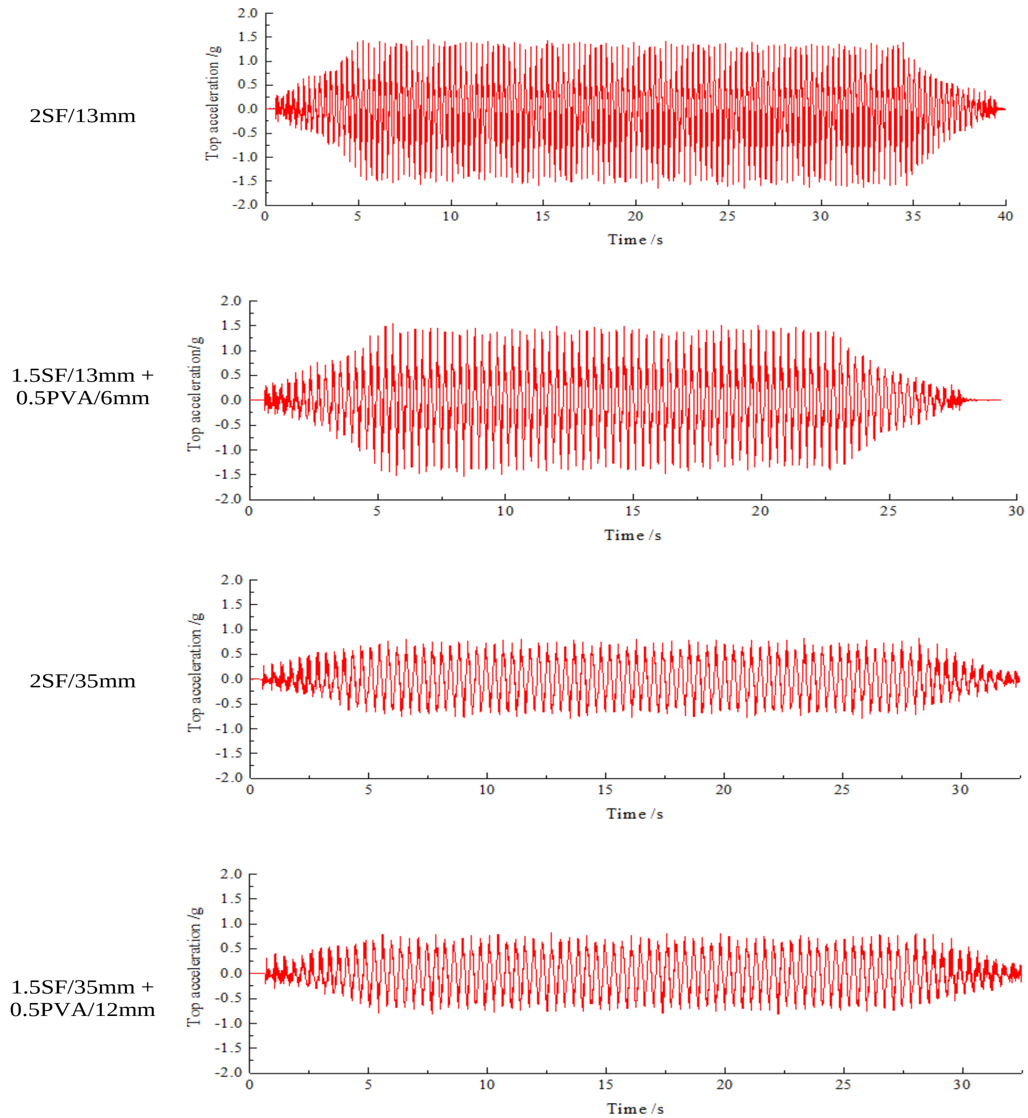


Figure 4: Column top acceleration versus time curves

4.2 Dynamic properties

Figure 4 illustrates the curves of column top-acceleration versus time for all composites. The 2SF/13mm and 1.5SF/13mm + 0.5PVA/6mm had presented better acceleration than those of 2SF/35mm and 1.5SF/35mm + 0.5PVA/12mm cementitious composites. In case of short-steel PVA fiber, the partial substitution of PVA lead to in reduced top-acceleration time curve of cementitious composite. However, the substitution of long PVA fibers in 1.5SF/35mm + 0.5PVA/12mm cementitious composite almost showed the stable performance. This short length of PVA fibers caused the reduction in acceleration due to shorter development length ultimately had low bond strength with cementious composites. In addition, the inclusion of PVA fibers produce new interfaces in composites that could result in low strength performance. Same conclusion is also reported in the literature [15]. In contrast, the long PVA fiber replacement in 1.5SF/35mm + 0.5PVA/12mm composite had proper development length and showed proper bond. This resulted in increased acceleration by fiber bridging and eventually restricted the crack growth in composites. The steel fiber and PVA fiber will result in fiber pull out or fiber fracture ultimately consume more energy and improved the performance under dynamic load. These fibers does not allow the crack to propagate and act as bridge between the cracks in composites.

CONCLUSION

The current study presents the compressive and dynamic response of hybrid fibers (steel and PVA fiber) in cementitious composites. The compressive strength and peak strain are determined under static load. The dynamic test is performed on hydraulic shaker with single degree of freedom condition and the curves of column top-acceleration verses time are studied. The following conclusions are made:

- The degree of decrement in compressive strength is more in short length hybrid fibers cementitious composites than those of long length hybrid fiber cementitious composites.
- The addition of long length hybrid fibers in composites improved the peak micro strain than that of short length hybrid fiber reinforced cementitious composites.
- The long PVA fiber replacement in 1.5SF/35mm + 0.5PVA/12mm composite indicated better acceleration performance because of fiber bridging that provides crack arresting mechanism.
- The steel fibers and PVA fibers offers the resistance against cracking by bridging across it at their particular scale ultimately caused the improvement in static and dynamic properties of hybrid fiber reinforced cementitious composites.

Further study is necessary with different lengths, contents, types and sizes of hybrid fiber in cementitious composites for enhanced performance under dynamic loading. Future work is to perform the SEM and XRD analysis for understanding the mechanism of hybrid fibers with matrix under dynamic load.

ACKNOWLEDGMENT

The authors would like to acknowledge the support of this work by the Natural Science Foundation of China under Grant No. 51678111 and No. 51478082. The financial support from China Scholarship Council (CSC) for PhD studies of Engr. Mehran Khan at Dalian University of Technology, China is gratefully acknowledged. The authors are also thankful to Dr. Cong Zhang and his research group for their help during the lab work. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] A. H. H. Al-Masoodi, A. Kawan, M. Kasmuri, R. Hamid, and M. Khan, "Static and dynamic properties of concrete with different types and shapes of fibrous reinforcement," Construction and Building Materials, vol. 104, pp. 247-262, 2016.

[2] E. Erdogmus, "Use of fiber-reinforced cements in masonry construction and structural rehabilitation," Fibers, vol. 3, pp. 41-63, 2015.

[3] M. Khan and M. Cao, "Effect of hybrid basalt fibre length and content on properties of cementitious composites," Magazine of Concrete Research, pp. 1-12, 2019.

[4] H. Kim, G. Kim, S. Lee, M. Son, G. Choe, and J. Nam, "Strain rate effects on the compressive and tensile behavior of bundle-type polyamide fiber-reinforced cementitious composites," *Composites Part B: Engineering*, vol. 160, pp. 50-65, 2019.

[5] B. H. Osman, X. Sun, Z. Tian, H. Lu, and G. Jiang, "Dynamic Compressive and Tensile Characteristics of a New Type of Ultra-High-Molecular Weight Polyethylene (UHMWPE) and Polyvinyl Alcohol (PVA) Fibers Reinforced Concrete," *Shock and Vibration,* vol. 2019, 2019.

[6] Y. Wu, W. Song, W. Zhao, and X. Tan, "An Experimental Study on Dynamic Mechanical Properties of Fiber-Reinforced Concrete under Different Strain Rates," *Applied Sciences,* vol. 8, p. 1904, 2018.

[7] M. Khan, M. Cao, and M. Ali, "Effect of basalt fibers on mechanical properties of calcium carbonate whisker-steel fiber reinforced concrete," *Construction & Building Materials* vol. 192, pp. 742-753, 2018.

[8] M. Khan, M. Cao, and M. Ali, "Cracking behaviour and constitutive modelling of hybrid fibre reinforced concrete," *Journal of Building Engineering,* p. 101272, 2020.

[9] A. Noushini, B. Samali, and K. Vessalas, "Effect of polyvinyl alcohol (PVA) fibre on dynamic and material properties of fibre reinforced concrete," *Construction and Building Materials*, vol. 49, pp. 374-383, 2013.

[10] Q. Fu, D. Niu, J. Zhang, D. Huang, Y. Wang, M. Hong, *et al.*, "Dynamic compressive mechanical behaviour and modelling of basalt–polypropylene fibre-reinforced concrete," *Archives of Civil and Mechanical Engineering*, vol. 18, pp. 914-927, 2018.
[11] H. Allahyari, I. M. Nikbin, S. Rahimi, and A. Allahyari, "Experimental measurement of dynamic properties of composite slabs from frequency response," *Measurement*, vol. 114, pp. 150-161, 2018.
[12] Z. Xu, H. Hao, and H. Li, "Experimental study of dynamic compressive properties of fibre reinforced concrete material with different fibres," *Materials & Design*, vol. 33, pp. 42-55, 2012.
[13] M. Cao, C. Xie, and J. Guan, "Fracture behavior of cement mortar reinforced by hybrid composite fiber consisting of CaCO3 whiskers and PVA-steel hybrid fibers," *Composites Part A: Applied Science Manufacturing*, vol. 120, pp. 172-187, 2019.
[14] ASTM C39, "C39/C39M-18: Standard test method for compressive strength of cylindrical concrete specimens," *ASTM International, West Conshohocken, PA*, vol. 192, 2018.
[15] M. Cao, C. Zhang, Y. Li, and J. Wei, "Using calcium carbonate whisker in hybrid fiber-reinforced cementitious composites," *Journal of Materials in Civil Engineering*, vol. 27, p. 04014139, 2014.

EFFECT OF U-SHAPED GFRP SHEAR KEYS ON THE BOND BETWEEN GFRP PLATE AND CONCRETE

[a] Hu Yi, [b] Asad Zia, [c] Hu Rui, [d] Zhang Pu
a: School of Civil Engineering, Zhengzhou University, China, huyi@gs.zzu.edu.cn
b: School of Civil Engineering, Zhengzhou University, China, asadzia005@gs.zzu.edu.cn
c: School of Civil Engineering, Zhengzhou University, China, hurui1117@163.com
d: School of Civil Engineering, Zhengzhou University, China, zhpu@zzu.edu.cn

Abstract- The role of the bond between fiber-reinforced polymer (FRP) interface and concrete carries a key role for an interface-concrete composite structure. Various researches are conducted to study the effectiveness of different techniques for improving the bond between the FRP strips and concrete. The current study evaluates the effectiveness of the new type of U-shaped GFRP shear key on the bond between the GFRP plate and concrete. Specifically, double-lap shear tests are conducted on specimens with GFRP shear key bonded GFRP plates to evaluate the rupture modes, the extreme load, the stiffness of interface (interfacial), and curves with load on the y-axis and slip on the x-axis for static loading. The tests are conducted on the double-lap shear specimens sized 514 mm x 100 mm x 100 mm. The bond length (222.5 mm) of the GFRP plates is kept higher than that of the effective bond-length bonded with Type A epoxy resin. C60 concrete having 184 kg, 392 kg, 660 kg, 1214 kg, and 2.94 kg of water, cement, sand, aggregates, and water reducer, respectively per $1m^3$ of the mix is used. The influence of the shear key and its position variation i.e. 80 mm and 160 mm from the loading end is evaluated in comparison to the GFRP-concrete double-lap shear specimen without a shear key. The use of shear keys along with the interface imparts significant enhancement in the bond between the concrete and GFRP plate. Shear key located at 80 mm from loaded end performed well as compared to that at 160 mm in increasing bond strength between concrete and GFRP plate. It can be concluded that the gap between the shear key and loading end also has a considerable effect in increasing the bond between concrete and GFRP plate.

Keywords- GFRP Shear Key, Interfacial Bond, GFRP Plate, Concrete

1 INTRODUCTION

Fibre Reinforced Polymer (FRP) has noticeable benefits such as high resistance to corrosion, fatigue, lightweight resistance, and huge strength. Being a structural material, it can be the best choice as an alternative to steel. One of the effective ways to get rid of issues due to corrosion of steel in a severe environment is to use FRP [1]. Advantages of the FRP-concrete composite structure encompass a higher level of industrialization, lightweights, elevated strength, design versatility, and zero corrosion as compared with structures of the traditional materials [2-4]. Therefore, the application and development of FRP materials with ultra-high durability and reinforced concrete composite structures are getting more attention.

Interface bonding between concrete and the FRP plate has the role of a medium for load transmission from concrete to FRP plate. Therefore, interface bonding has a key role in increasing the strength of concrete by the FRP plate. Studies showed that the interface was prone to interfacial peeling and slippage during the application of load, which affected the shear resistance of the interface of the composite structure, resulting in premature separation of FRP materials and concrete and not able to fully exercise their full mechanical strengths [5-7].

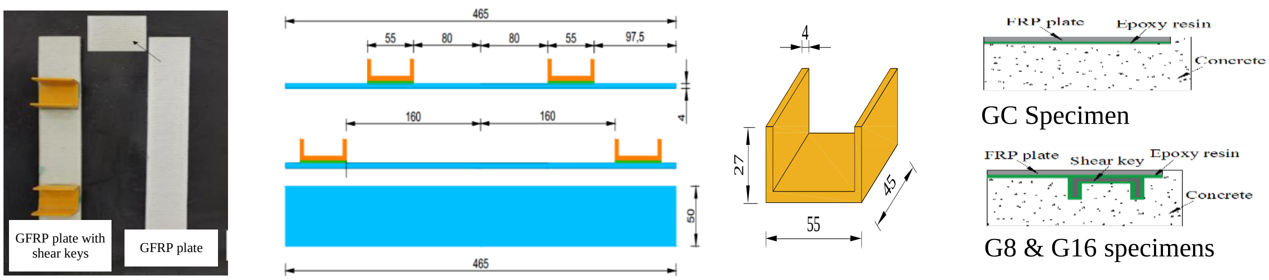
Numerous researches are conducted so far related to the mechanical characteristics of the FRP-concrete composite interface. The shear mechanical and shear properties of the FRP-concrete interface were investigated for the three types (i. bolted, ii. Hybrid, and glued) of connections [8]. The best shear resistance was noticed for the hybrid connection along with an increase in extreme load capacity with an increase in the number of bolts. The use of a shear key (SK) with an interface of FRP and concrete was also noticed to be an adequate interface type of combination for improving the bond strength between concrete and FRP plate [9]. But the reported studies are limited to the dry bond interface only.

Consequently, in the current study, double-lap shear tests are performed on specimens with GFRP shear key bonded GFRP plates. The outcomes are reported in the modes of failure, the ultimate capacity of load, the interfacial stiffness, and the curves of load vs slip for the static loading.

2 EXPERIMENTAL PROGRAM

A. Materials

P.O.42.5, an Ordinary Portland cement [10] is used. The maximum size of gravel and river sand is 20 mm and 0.5 mm, respectively. Glass fiber reinforced polymer (GFRP) plates having unidirectional fibers with transverse surface mats are used. The nominal thickness and width of the GFRP plate are 4 mm and 50 mm, correspondingly. The tensile strength, Young's modulus, and Limit elongation of GFRP plates measured as per the appropriate standards of China [11] are 516 MPa, 33 GPa, 1.60 %, respectively. The U-shaped GFRP shear keys are used having a size of 55 mm × 45 mm× 27 mm × 4 mm. Fig. 1 presents GFRP plates, locations of shear keys on the plates of GFRP, size of the shear key, and schematic view of an interface for each type of specimen. For increasing the force of anchoring, the area of contact between the plates of GFRP and shear keys is roughened and then epoxy resin is used for pasting the shear key on the exact locations of the GFRP plate. The adhesive bond between GFRP shear keys and GFRP plates is increased by keeping a steel block on the top of GFRP shear keys for 7 days. The Tensile strength, Modulus of elasticity, and Limit elongation of epoxy resin named as Type A measured as per the appropriate standards of China [12] are 34.7 MPa, 2.42 GPa, and 2.71%, correspondingly.



(a) (b) (c) (d)

Fig.1 (a) GFRP plates, (b) locations of the shear keys on the GFRP plates, (c) Shear key size, and (d) schematic view of the interface

B. Casting and testing procedure

A typical preparation procedure is shown in Fig. 2. The specimens are cured in the standard room of curing by following the concerned standard of China [13]. Curing is carried out for 28 days. The average compressive strength of C60 concrete measured as per the relevant standard of China [14] is 72.0 MPa.

(a) Preparation of WB interface specimens (b) Preparation of SK interface specimens (c) Concrete casting (d) Concrete curing

Fig. 2 Preparation procedure of test specimens

C. Nomenclature of specimens and loading scheme

Three samples are tested for each type of specimen. An average of three results is taken as a corresponding property for each type of specimen. The control specimen without a shear key is named GC while the specimen with the shear key at 80 mm from the loading end is named as G-8 while that of other with 160 mm distance from the loading end is named as G-16. Total 9 number of samples. Universal testing machine with 100 kN capacity is used for Double lap shear tests, as revealed in Fig. 3.

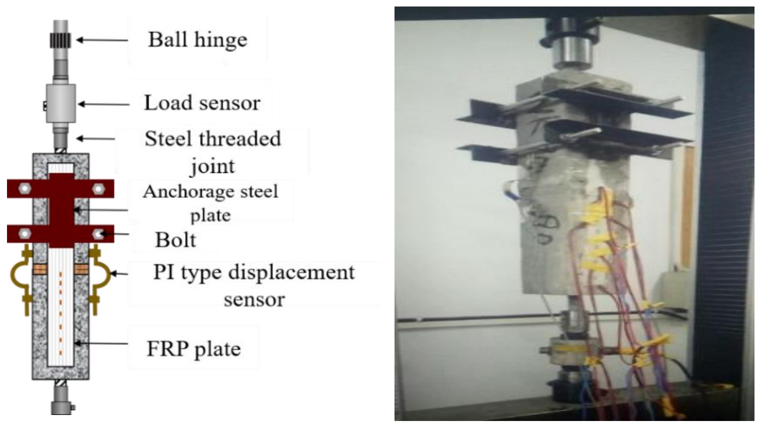


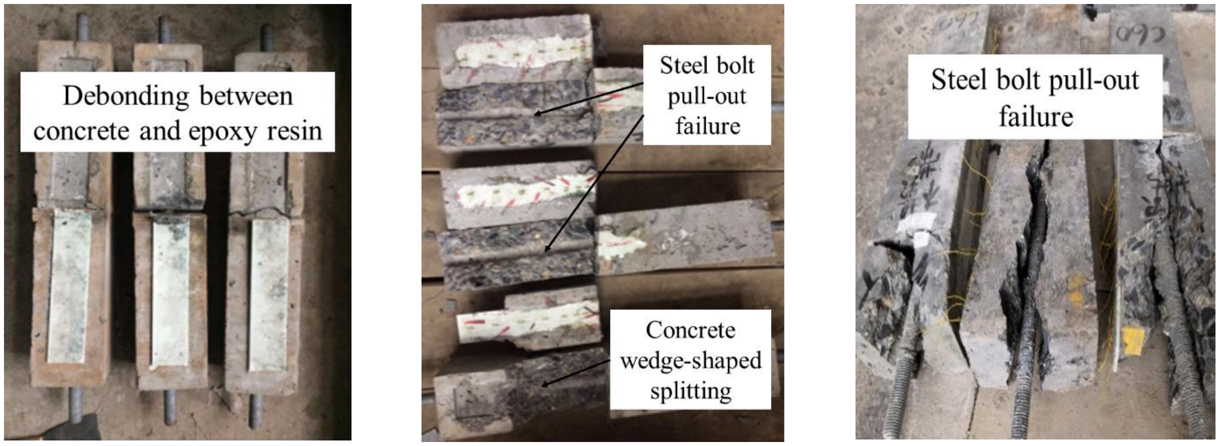
Fig.3 Graphic illustration of the loading device

3 TEST RESULTS AND ANALYSIS

A. Modes of failure

Three different modes of rupture are observed for the specimens:(1) Detach between the layer of the epoxy resin and the coating of concrete as a result of the deficient union of the interface of epoxy resin and concrete, (2) Pull-out of steel bolt happened for the reason that the force of fastening between concrete and the steel bolt was less in comparison to that of the bearing strength of the interfacial, and (3) Failure due to wedge-split of concrete between the wooden partition and shear key, the possible reason may be smaller concrete's tensile strength as compared to the interfacial bearing strength attributable to the high concentration of the stress between wooden partition at the loading end and GFRP shear key. The same observations were reported in other research studies [7,15].

Figure 4a displays the rupture mode noticed for the CG specimen, which was categorized by interfacial peeling amid the FRP plate and epoxy resin. It shows that full transfer of the load between the concrete and GFRP plate is not achieved due to pre-mature peeling of the GFRP plate. Shear key fail failure for one sample and steel bolt pull-out failure for two samples accompanied by the wedge-split of the concrete are observed for G8 specimens (with the shear key at 80 mm from the loaded end) as shown in Figure 4b. This supports the role of the shear key in utilizing the greater strength of the GFRP plate in supporting the applied loads and moments in addition to concrete without debonding. The rupture mode of the specimen (G16) having shear key distance at 160 mm is the failure of due to pull-out of steel bolt without any damage to the shear key as shown in Figure 4c. Pull-out of steel bolt is noticed, which could be described that the force of fastening between concrete and steel bolt was feebler as compared to the interfacial bearing capacity. And the wedge-split breaking of the concrete between the wooden partition and the shear key happened.



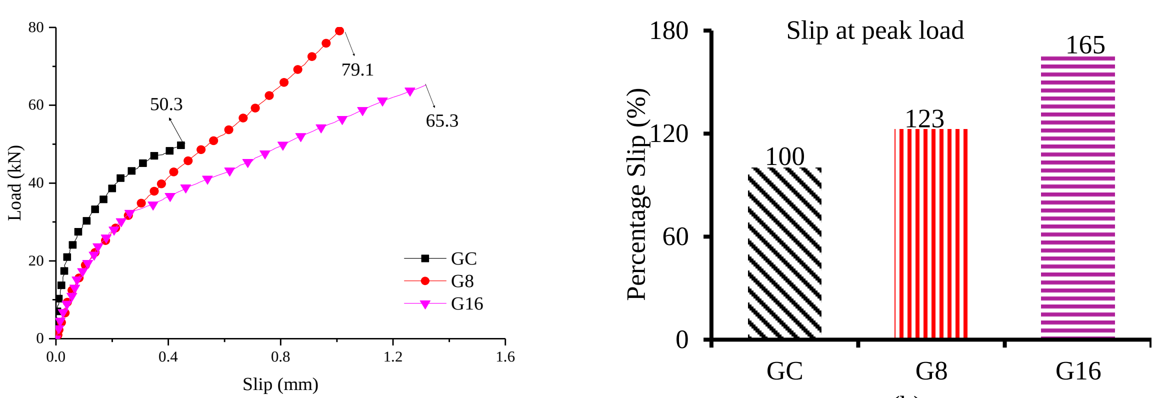
(a) CG (b) G8 (c) G16

Fig. 4 Interface failure modes of four interface of GFRP plate specimens

B. Load-slip curves

The load vs slip curves of each test specimen are given in Figure 5(a). The interface anti-slip stiffness can be judged and compared by the slope of the initial elastic phase of the load-slip curve. The lowest slip of 0.8 mm is noticed for the epoxy resin GC specimen having GFRP plates without any shear key. While the slip for the G8 and G16 specimens having GFRP plates containing resin of epoxy on the bonded interface with the shear key is 0.98 mm and 1.32 mm, respectively. By equating the load carrying capacities, G8 outperformed the companions in increasing the load carrying capability of the specimen. The peak load of the G8 is 28.8 kN and 13.8 kN more than that of the GC and G16, respectively, as shown in Figure 5(a). The percentage comparison of the slip at peak load are shown in Figure 5(b). The slip at peak load of G8 and G16 is 23% and 65%, respectively greater than that of the GC.

GC specimens provided a satisfactory level of composite action. For G8 and G16, the bond of the FRP plate and shear key can be more fragile as compared to that exists between concrete and the FRP plate, which leads to a decline in the interfacial stiffness. Conclusively, the rate of slip increased for the shear key specimen with a low gradient of the primary elastic phase of the load-slip curve in comparison to that of the GC specimen. A variation in the positions of the shear key has tiny influence over the interfacial stiffness of the elastic phase. But the larger effect in the post-elastic region of the curve. It can be explicated that a smaller distance from the loading end was expected to produce a huge concentration of stress between the loaded end and shear key, and at a larger distance from the loading end do not effectively limit the interfacial detachment.



(a) (b)

Fig. 5 (a) Load-slip curves, (b) Percentage comparison of slip at peak load

C. Extreme load capacity

Figure 6(a) displays the extreme load capacity of the specimens. The extreme load of 47.27 kN, 77.57 kN, and 60.17 kN are observed for GC, G8, and G16, respectively. The extreme load of the G8 is 30.3 kN and 17.4 kN larger than that of the

GC and G16, respectively. It is observed that the shear key enhanced the extreme load capacity significantly as compared to that of the specimen without a shear key.

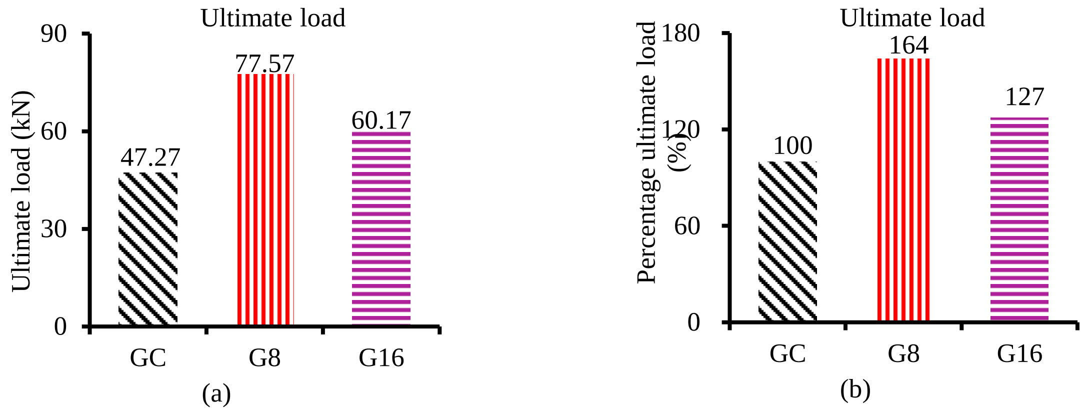


Fig. 6 Ultimate loads (a) extreme load capacity (b) Percentage comparison of extreme load capacity

Most importantly the shear key gap from the loading end also affected the load carrying capacity. It can be observed that the extreme load capacity of the GC and G16 is considerably lesser as compared to that of the specimen (G8) with a shear key located at 80 mm from the end of loading. The percentage comparison between the extreme load of the specimens is demonstrated in Figure 6(b). The extreme load-carrying capacity of the G8 and G16 is 64% and 27% greater than that of the GC. Variation in the shear key location showed a significant impact on the extreme load capacity of the specimen. An increase in the gap of the shear key from the loading end negatively affected the extreme load capacity of the specimen, indicating a decrease in the bond strength. This confirms that the distance of the shear key from the loaded end also needs to be considered to ensure better bonding between the interface and GFRP plates for attaining the required increase in strength. As per the considered case, the gap of the shear key from the loading end is inversely proportional to the bond strength between concrete and the GFRP plate.

4 CONCLUSIONS

Subsequent conclusions are made from the present experimental results:

- Interfacial peeling (premature detachment) between the GFRP plate and epoxy resin is noticed for the specimen without GFRP shear key while the introduction of shear key helped in utilizing the full strength of the GFRP plates without any interfacial peeling and interface failure.
- At the peak loads, the slip of 0.8 mm, 0.98 mm and 1.32 mm are noticed for the GC (GFRP plates reinforced specimen without shear key), G8 (GFRP plates reinforced specimen with the shear key at 80 mm from the loaded end), and G16 (GFRP plates reinforced specimen with the shear key at 160 mm from the loading end), respectively.
- The extreme load-capacity of G8 and G16 is 64% and 27% greater than that of the GC

The experimental outcomes showed significant improvement due to the use of GFRP shear keys along with the interface of GFRP plates in the extreme load capacity and capacity of the peak load of the double-lap shear specimen. Besides, premature debonding of GFRP plates is also prevented by GFRP shear keys. Conclusively, the shear keys improved the bond between concrete and the GFRP plate. Further investigations are required to evaluate the optimized location and size of the GFRP shear keys for attaining the maximum possible strength enhancement.

ACKNOWLEDGMENT

The authors acknowledge the financial support received from Zhengzhou University, China.

REFERENCES

[1] Hollaway LC. A review of the present and future utilisation of FRP composites in the civil infrastructure with reference to their important in-service properties. Constr Build Mater. 2010; 24:2419-45.

[2] Ceroni F, Cosenza E, Gaetano M, Pecce M. Durability issues of FRP rebars in reinforced concrete members. Cement Concrete Comp. 2006; 28:857-68.

[3] Feng P, Wang J, Wang Y, Loughery D, Niu DT. Effects of corrosive environments on properties of pultruded GFRP plates. Compos Part B-Eng. 2014; 67:427-33.

[4] Ta¨ljsten B. Plate bonding, strengthening of existing concrete structureswith epoxy bonded plates of steel or fibre reinforced plastics. Doctoral Thesis 1994:152D. Division of Structural Engineering, Lulea˚ University of Technology 1994; 308 pp. ISSN 0348-8373.

[5] Teng JG, Lu XZ, Ye LP, Jiang JJ. Bond-slip models for interfaces between externally bonded FRP and concrete. In: FRP composites in civil engineering –CICE; 2004. p. 55-68

[6] Oehlers DJ. FRP plates adhesively bonded to reinforced concrete beams: Generic debonding mechanisms. Adv Struct Eng. 2006; 9:737-50.

[7] Ozbakkaloglu T, Fang CF, Gholampour A. Influence of FRP anchor configuration on the behavior of FRP plates externally bonded on concrete members. Eng Struct. 2017;133:133-50.

[8] Zou et al. FRP stay-in-place form and shear key connection for FRP-concrete hybrid beams/decks. Composite Structures, (2018); 192: 489-499.

[9] Wang YL, Hao QD, Ou JP. Study on Bonding Properties of FRP Plate and Concrete with Shear Bond. Journal of Shenyang Jianzhu University (Natural Science) 2007; 23(4): 533-537.

[10] Chinese Standard GB/T 50081, Standard for test method of mechanical properties on ordinary concrete, China Standard Press, Beijing, 2002.

[11] Chinese Standard GB/T 2567, Test methods for properties of resin casting boby, China Standard Press, Beijing, 2008.

[12] Chinese Standard GB 175, Common Portland Cement, China Standard Press, Beijing, 2007.

[13] Chinese Standard GB/T 50081, Standard for test method of mechanical properties on ordinary concrete, China Standard Press, Beijing, 2002.

[14] Chinese Standard GB/T 50152, Standard for test method of concrete structures, China Standard Press, Beijing, 2012.

[15] Zhang, Pu, et al. "Mechanical performance of the wet-bond interface between FRP plates and cast-in-place concrete." Journal of Composites for Construction 18.6 (2014): 04014016-1-04014016-9.

EFFECT OF WASTE FOUNDRY SAND (WFS) ON STRENGTH AND DURABILITY OF PRESSED FIRED CLAY BRICKS

a Luqman Ali, b Muhammad Nasir Ayaz Khan, bYasir Rasheed
a: Structural Engineering Department, Military College of Engineering NUST, Risalpur, luqmanyousafzai89@gmail.com (corresponding author)
b: Civil Engineering Department, HITEC University Taxila, Pakistan, nasir.ayaz@hitecuni.edu.pk; yasir.rasheed@hitecuni.edu.pk

Abstract- Bricks are significant construction material due to their cost and excellent properties such as durability and compressive strength. With the increasing demand in construction, scarcity of natural material is nowadays a major problem. To counter this, waste foundry sand has been utilized in fired clay pressed bricks in different proportions by replacing clay. Compressive strength and durability were studied as main properties. It was observed that replacing clay with 10% waste foundry sand increases compressive strength. Incorporation of 10% waste foundry sand in bricks resists acid attack and minimum weight loss was observed. Scanning electron microscope analysis suggested the crystallization of bricks by incorporation of waste foundry sand. It is recommended that waste foundry sand can be effectively used in bricks to enhance its properties.

Keywords- Acid Attack, Brick, Durability, Foundry Sand, Scanning Electron Microscope (SEM)

1 INTRODUCTION

Soil has been used in different forms as the construction material for centuries. In developing countries, with the least demand for natural resources, earth construction is considered as the most efficient and economic. However, with increasing demand in construction material as well challenges with waste disposal, both developed and developing countries are on a mission to impede scarcity of natural resources [1].

Construction industry is one of the major industries to use waste in construction material promising to alter and enhance material properties. Investors, builders and stack holders are grueling to use alternates materials that provide the same or enhanced properties with low cost and ecofriendly. To counter this problem, researchers around the globe are using waste products in engineering materials with promising cost and superior properties than existing. For instance, concrete has been incorporated with fly ash, ground granulated blast furnace slag (GGBS), glass powder, marble powder, bentonite, waste foundry sand with multiple goals to enhance the properties of concrete as well utilization of discarded materials [2-6].

Brick is the oldest, economic and commonly used material, was first used 6000 years ago [7]. Bricks are significant material in construction due to its cost and outstanding properties such as its compressive strength and great durability. According to a report, its worldwide production is about 1.3 trillion units per year and increasing [8]. Pakistan ranks third in contribution to the worldwide production of fired clay bricks which is about 59 billion units per year. With this huge consumption of bricks, the diminishing of natural resources is a major problem. In recent decades, mainly in developing countries, researchers have been using waste materials in bricks by replacing fully or part of clay. For instance, the use of granulated blast furnace slag, rubber, waste processed tea, cotton waste, rice husk ash, industrial wastewater, limestone dust, sawdust, fly ash, cigarette butts, plastics waste and waste papers. All these researches are evident for enhanced properties of brick which are mainly compressive strength, water absorption and durability. The brick properties along with material also depend upon the method of manufacturing, drying and firing [9-14].

Foundry sand is a byproduct in foundry and metal casting industries. Million tons of foundry sand is discarded from industries each year. According to a report, 104.12 million tons of both ferrous and nonferrous casting is carried out each year. Casting done with cast iron and steel are called ferrous industries while casting with aluminum, brass and bronze are termed as non-ferrous. Silica is the main constituent of foundry sand which is 80-95%. Other constituents such as iron oxide, alumina, calcium are also present but in very little amount. After casting, the foundry sand is discarded and dumped which creates landfilling and environmental pollution. Foundry sand has been used before in construction material such as concrete which may enhance the properties at low cost [6,15].The foundry sand has been also utilized in making fired clay bricks which resulted in significant properties compared to commercial bricks [16].

In this research, an attempt has been made to incorporate Waste Foundry Sand (WFS) in fired clay bricks by replacing clay in different proportions. The machine pressing method was used for manufacturing brick and firing in a traditional tunnel oven. Compressive strength and durability tests were conducted. Scanning Electron Microscope (SEM) was used to study the microstructure of bricks.

2 EXPERIMENTAL PROCEDURES

In this research, bricks were manufactured from the mixture of fired clay and Waste Foundry Sand (WFS). The WFS was collected from Heavy Mechanical Complex (HMC) Taxila, Pakistan at their dumping site. The large lumps of sand (bounded by chemicals) were separated at the site and clean sand was taken into bags. The sand was then taken into the lab for initial testing such as sieving, water absorption, and specific gravity. The physical properties of WFS is given in Table 1. The sieve analysis of foundry sand is given in figure 2, indicating more fine particles than natural sand. The elemental composition of the WFS has been analyzed through Energy Dispersive X-ray (EDX) technique in Central Resource Laboratories (CRL), University of Peshawar, Pakistan. The peaks generated by the corresponding elements are shown in Figure 1.

Table 1- Physical Properties of WFS and fired clay

Material	**Specific Gravity**	**Absorption (%)**	**Fineness Modulus**	**Moisture content (%)**	**OMC**	**Plastic Limit**
WFS	2.68	0.89	2.11	2.67	_	Non plastic
Fired clay	2.64	-	-	-	8.62	34

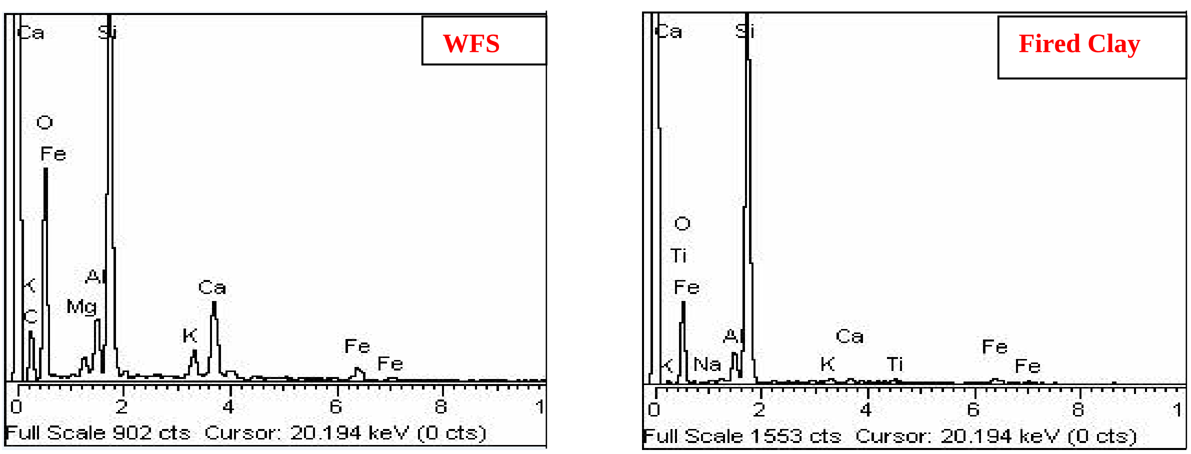


Figure 1: EDX analysis of WFS and fired clay

The fired clay was collected from Standard Ceramics, Hattar, Pakistan. The clay was subjected to some initial physical tests. The physical properties of clay are given in Table 1. The elemental composition of the clay was found through Energy Dispersive X-ray (EDX) technique in Central Resource Laboratories (CRL), University of Peshawar, Pakistan indicating less silica then WFS as shown in Figure 2.

The mixing, casting, drying and firing of bricks were done in the industry named Standard Ceramics, Hattar Pakistan. Total of six mixes of bricks were prepared by replacing clay with WFS. The replacement level of WFS was 10%, 20%, 30%, 40%, 50% and 60% for each set of bricks. Each brick was designated by the level of replacement of clay with WFS. For instance, FB1 brick shows "Fired Clay Brick with 10% incorporation of WFS".

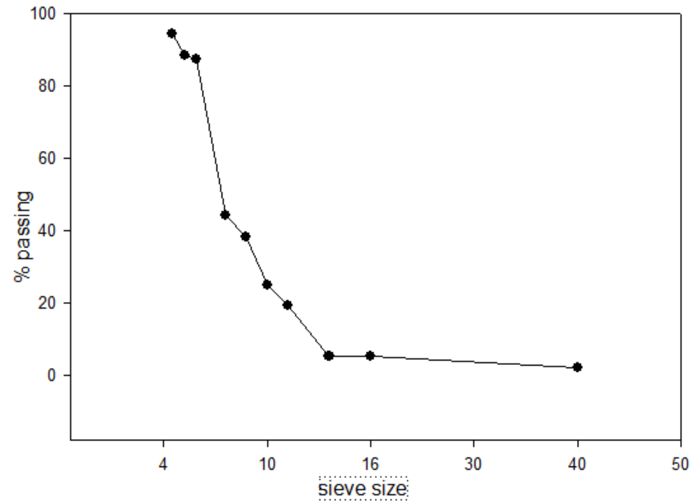


Figure 2: Sieve analysis of WFS

After mixing of raw materials, 15% water by the weight of material is added to each mix. it may be worth noting that machine pressed bricks to require less water than traditional hand mix bricks. After that, the mixture was taken to a hydraulic pressing machine. The pressing machine is electric driven which presses the raw material with 20.6 MPa force and mold the raw material into standard brick size (9" x 4.5"x 3"). After removing from the pressing, the bricks were carefully stacked for drying in sun. After 6-8 days, the unfired bricks were loaded into conveyer for firing. The firing was carried out in a traditional tunnel oven which operates on natural gas. The length of the oven was measured 262 feet and its diameter was about 5 feet. The firing process is subdivided into three steps. In the first step, the bricks are loaded on an auto electric conveyer belt which moves with certain fixed speed into the oven. In this step, the further drying of the bricks occurs which eliminates the free water present in bricks. The temperature in this step ranges from 100 ^{O}C to 450 ^{O}C. In the second step, the crystallization process takes place and the highest temperature noted in this step was 1200±10 ^{O}C. In this step, the bricks are burnt completely and moved to third step.

The third step is linked with exit side of the tunnel in which cooling of the bricks process initiates. At the exit, the temperature of the brick was noted 60±5 ^{O}C. The firing process is completed in five days. After removal from tunnel; the bricks are left for cooling for few hours. After complete cooling, the bricks were collected and taken into a laboratory for compressive strength test, water absorption and durability. The whole process is demonstrate in Figure 3.

Before the compressive strength test, the bricks were made leveled from both sides so that the force applied may remain constant throughout testing. The compressive strength values were noted for three set of bricks for each mix. For durability test, the bricks were immersed in 10% sulphuric acid (H2SO4) concentrated water for 28 days. Before immersing, the bricks were carefully weighed and noted. After 28 days, the bricks were weighed again and then taken into compression testing machine. The method of sampling, stacking and testing was in accordance with ASTM C67 / C67M-20 [17].

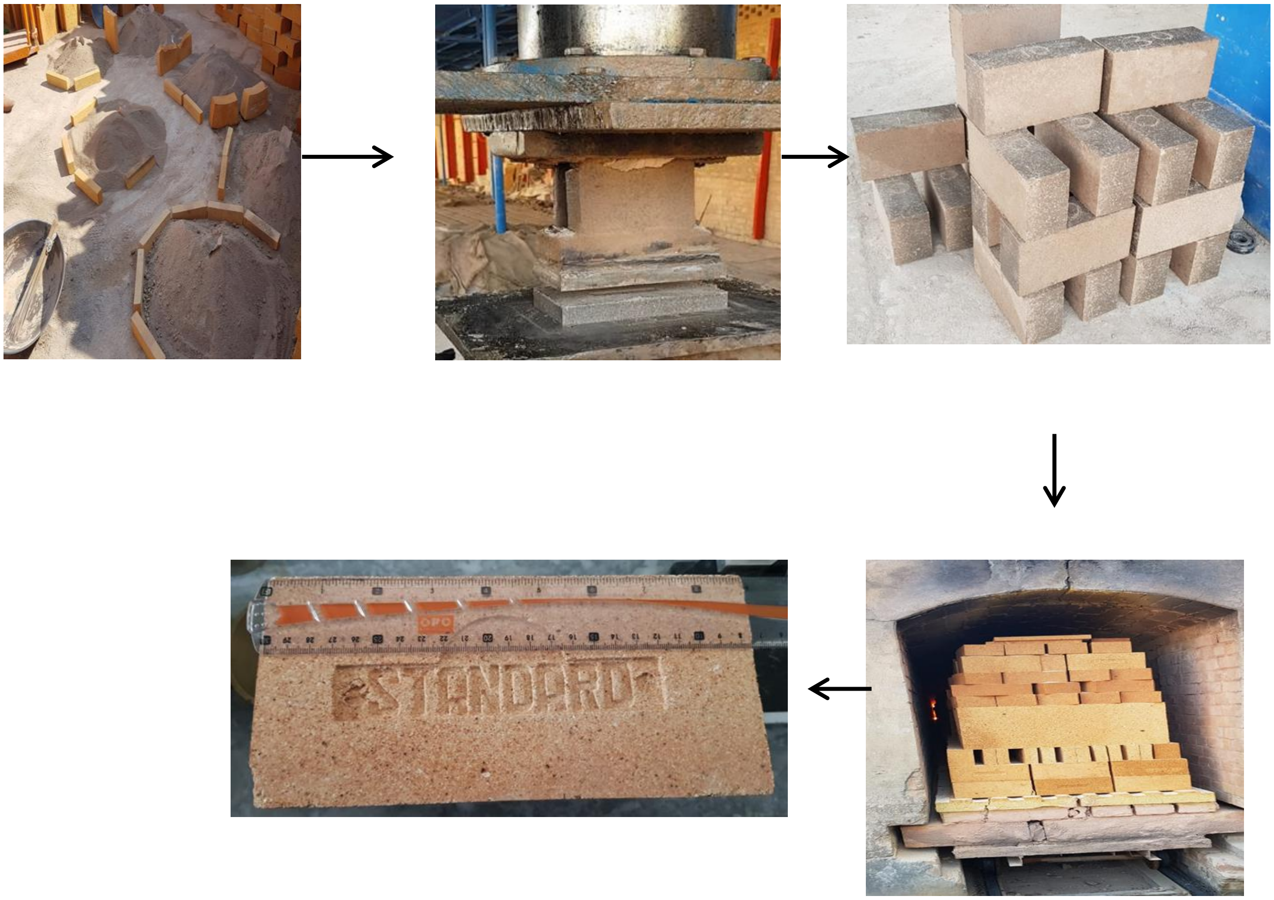


Figure 3: Process of brick making from mixing, pressing, drying, firing and final brick

3 RESULTS AND DISCUSSION

3.1 Compressive strength

All the bricks were tested in compression testing machine. For each mix, three sets of bricks were tested and values were noted. It was observed that the highest strength was noted for FB1 brick (incorporated with 10% WFS), which was 18.97 MPa. The control specimen having designated as FB0 (having no WFS) shows the strength of 18.20 MPa, which was lower than FB1 by 4.24%. The lowest strength was noted for FB6 brick (incorporated with 60% WFS), which was 10.81 MPa lower than control mix by 41.70%. The bricks FB2 and FB3 showed almost similar strength to control mix as shown in the figure.

The increase in strength is attributed to the fine size of WFS which fills the pore of the mixes. As a result, a compact dense structure is formed which completely crystallizes during sintering process at 1200 OC in oven. The slow and steady firing also takes a share in high strength. It may be noted that due to the high content of silica in WFS, the bricks were showing brittle behavior during testing i.e., sudden failure with large cracks. However, small cracks were observed for CM, FB1 specimens compared to other bricks. The lowest strength, as indicated was noted for FB6 specimens, which may be due to the abundance of WFS particles. All the particles were not able to fill the pores and as a result, non-crystallization of bricks occurred which results in lower strength.

3.2 Durability

The bricks were immersed in 10% H2SO4 concentrated water for 28 days. After removal, the brick was weighed and tested for compression test. It was observed that no significant weight loss was observed for mixes except FB5 and FB6. The weight loss for control mix was 3.31%. Mixes incorporated with WFS showed higher weight loss than control mix. For instance, FB1 specimen showed weight loss of 4.71% greater than control mix. The highest weight loss was found for specimens FB5 and FB6 which was 10.5% and 10.9% respectively as shown in Figure 5.

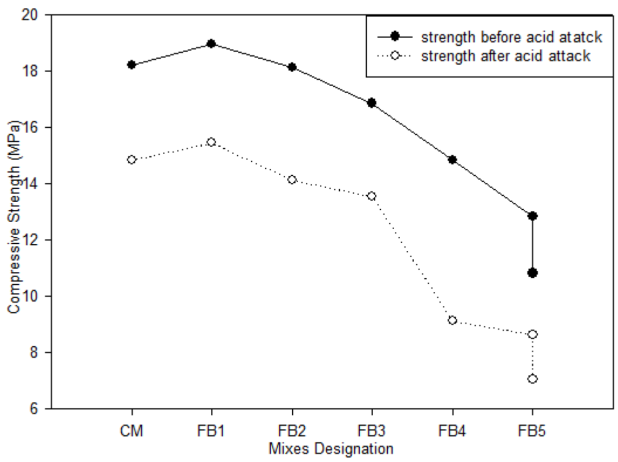


Figure 4: Compressive strength Vs Bricks Specimens

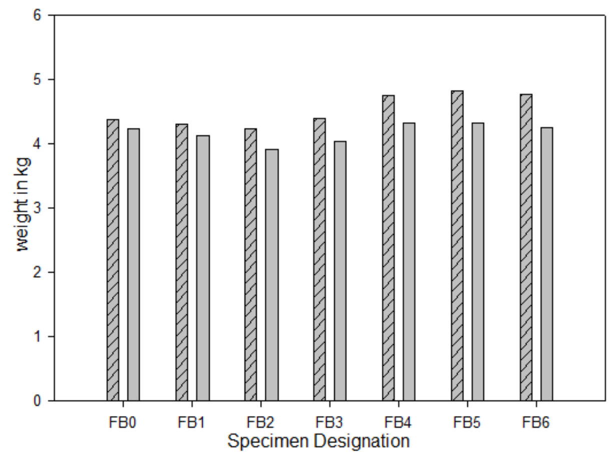


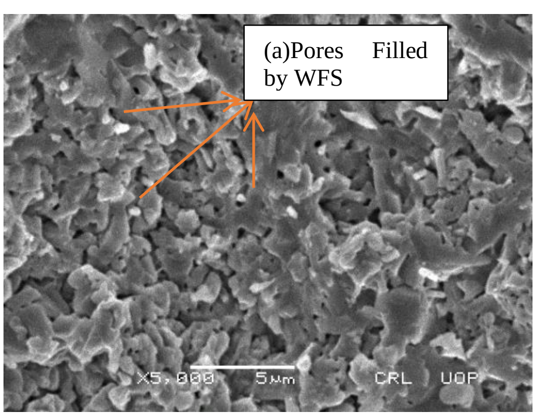
Figure 5: Weight loss variations after acid attack

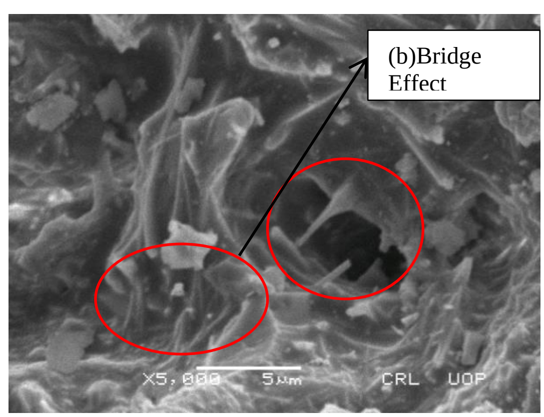
The bricks were also tested for compression strength after immersion in acid concentrated water. It was observed that the same trend was followed in strength after removal from acid. The strength of control specimen, FB1 and FB2 showed almost same strength. For instance, FB1 showed a little higher strength than control by 4.08% whereas FB2 showed little lower strength than control specimen by 4.8%. it was observed that FB5 and FB6 specimens affected more due to the acid attack. The reason for strength reduction is the more permeability of FB2 bricks. The strength of FB5 and FB6 specimen was lower than control specimen by 41.9% and 50.4% respectively as shown in Figure 4.

3.3 *Scanning Electron Microscope (SEM)*

This test is used to study the topography of the material as well composition at various intensity and magnification. The statement of compressive strength for FB1 specimens can be verified through SEM. It was observed that the pores are filled well by WFS particles, which makes it firm and dense structure. The bridging effect is quite visible, which offers tremendous resistance against loads as shown in Figure 5.

On the other hand, control specimen shows quite same micro properties as for FB1 specimen except that few pores are still left unfilled. It was observed from compressive strength test and durability that FB6 specimen affected more as compared to other specimens. Cracks are visible in FB6 specimen in SEM images. Moreover, there are unfilled pores present in greater density compared to other samples which make it a week and unable to sustain loads as shown in Figure 5.





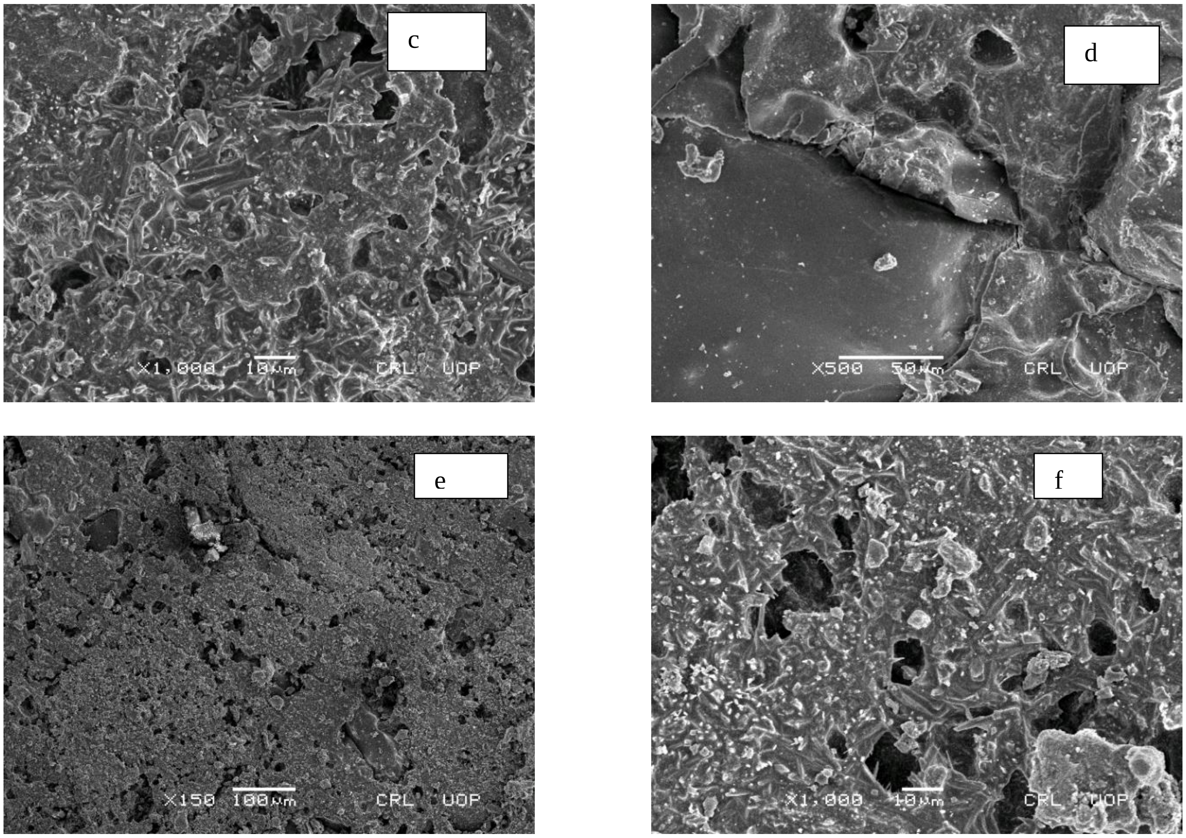


Figure 5: SEM FB1(a, b) ; CM (c, d); FB6 (e, f)

4 CONCLUSION

In this study, Waste Foundry Sand (WFS) has been utilized in bricks to study its properties. Following are the conclusion drawn from the study:

- The Energy Dispersive X-Ray technique shows that silica is the main and abundant element in WFS.
- Incorporation of 10% WFS in bricks gives maximum compressive strength. Beyond this replacement, the strength tends to decrease.
- Acid resistance was found maximum for brick specimens having 10% incorporation of WFS by replacing clay. Specimens having 60% WFS incorporated affected most against acid attack.
- It was observed that weight loss against acid is not significant in specimens except for bricks incorporated with 60% WFS.
- The scanning Electron Microscope analysis shows that bricks incorporated with 10% WFS crystallize completely during sintering temperature.

ACKNOWLEDGMENT

The authors are extremely thankful to Mr. Malik Sherafgan CEO Standard Ceramic Industries (Pvt) Ltd Hattar, Pakistan for providing us space for experimentation, firing of bricks and material free of cost.

REFERENCES

[1] A. L. Murmu and A. Patel, "Towards sustainable bricks production : An overview," *Constr. Build. Mater.*, vol. 165, pp. 112–125, 2018.

[2] S. U. Rehman, M. Noman, B. A. Abbasi, S. Campus, M. Nasir, and A. Khan, "The Influence of Thermo-Mechanical Activation of Bentonite on the Mechanical and Durability Performance of Concrete," applied sciences., vol. 9, no. 24, 2019.

[3] J. Skibsted and R. Snellings, "Cement and Concrete Research Reactivity of supplementary cementitious materials (SCMs) in cement blends," *Cem. Concr. Res.*, vol. 124, p. 105799, 2019.

[4] Sales, R. B. C., Sales, F. A., Figueiredo, E. P., dos Santos, W. J., Mohallem, N. D. S., & Aguilar, M. T. P. "Durability of Mortar Made with Fine Glass Powdered Particles," vol. 2017, pp. 1-9,2017.

[5] H. Hebhoub, H. Aoun, M. Belachia, H. Houari, and E. Ghorbel, "Use of waste marble aggregates in concrete," *Constr. Build. Mater.*, vol. 25, no. 3, pp. 1167–1171, 2011.

[6] R. Siddique, G. Singh, R. Belarbi, and K. Ait-mokhtar, "Comparative investigation on the influence of spent foundry sand as partial replacement of fine aggregates on the properties of two grades of concrete," *Constr. Build. Mater.*, vol. 83, pp. 216–222, 2015.

[7] W.S. Wahby, "Ancient masonry work in Egypt, China, and Rome: a comparative study", *13th International Brick and Block Masonry Conference Amsterdam*, 2004.

[8] Census-2016-Modern-Casting.pdf. Available at: http://www.foundryinfo-india.org

[9] M. N. Ayaz Khan, N. Liaqat, I. Ahmed, A. Basit, M. Umar, and M. A. Khan, "Effect of Brick Dust on Strength and Workability of Concrete," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 414, no. 1, 2018.

[10] A. A. Aliabdo and H. H. Hassan, "Utilization of crushed clay brick in cellular concrete production," *Alexandria Eng. J.*, vol. 53, no. 1, pp. 119–130, 2014.

[11] P. Palanisamy and P. S. Kumar, "Case Studies in Construction Materials E ff ect of molarity in geo polymer earth brick reinforced with fi brous coir wastes using sandy soil and quarry dust as fi ne aggregate . (Case study)," *Case Stud. Constr. Mater.*, vol. 8, pp. 347–358, 2018.

[12] G. Cultrone and E. Sebastián, "Fly ash addition in clayey materials to improve the quality of solid bricks," *Constr. Build. Mater.*, vol. 23, no. 2, pp. 1178–1184, 2009.

[13] M. Sutcu, H. Alptekin, E. Erdogmus, Y. Er, and O. Gencel, "Characteristics of fired clay bricks with waste marble powder addition as building materials," *Constr. Build. Mater.*, vol. 82, pp. 1–8, 2015.

[14] M. S. El-Mahllawy, "Characteristics of acid resisting bricks made from quarry residues and waste steel slag," *Constr. Build. Mater.*, vol. 22, no. 8, pp. 1887–1896, 2008.

[15] G. G. Prabhu, J. H. Hyun, and Y. Y. Kim, "Effects of foundry sand as a fine aggregate in concrete production," *Constr. Build. Mater.*, vol. 70, pp. 514–521, 2014

[16] Hossiney, N., Das, P., Mohan, M. K., & George, J. "In-plant production of bricks containing waste foundry sand—A study with Belgaum foundry industry," *j.cscm.*,vol. 9, 2018.

[17] ASTM C67 / C67M-20, Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile, ASTM International, West Conshohocken, PA, 2020, www.astm.org

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

COMPARATIVE STUDY ON THE SEISMIC PERFORMANCE OF BARE FRAME AND INFILLED FRAME RC STRUCTURES WITH BRICK MASONRY AND LOW STRENGTH CONCRETE BLOCK MASONRY INFILLS

[a] Raheel Asghar, [b] Asif Shahzad, [c] Syed Uzair Amjad, [d] Ali Akhtar
a: Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus, raheelasghar68@gmail.com
b: Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus, shahzaasif@gmail.com
c: Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus, uzairshah197@gmail.com
d: Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus, aliakhtarglt@gmail.com

Abstract - A practice of constructing RC frame structures with unreinforced masonry infill walls is being followed all over the world from the past few years. In the start, these masonries were considered as the non-structural elements of the building, but recent researches and studies have shown that the presence of these infill masonries greatly influence the seismic performance of RC structures. This research aims at the evaluation of seismic performance of bare frame, brick masonry infilled frame and low strength concrete block masonry infilled frame RC structures. For this, a six storey (G +5) commercial building being located in Abbottabad was selected for the analysis. Three models of this building namely bare frame, brick masonry infilled frame and low strength concrete block masonry infilled frame were prepared in ETABS 2015. These models were then analyzed by linear dynamic method of seismic analysis i.e. response spectrum analysis. The comparison between seismic performance of these models of the given building was made on the basis of maximum storey displacement, maximum storey drift ratio, base shear, time period and overall stiffness of the structure. From the results of the research, it was observed that when the effect of infill masonries was considered in the analysis, the performance of the building was observed to be greatly improved. Analyzing the results, it was concluded that presence of infill masonries greatly enhances the overall seismic performance of RC structures by increasing their strength, stiffness and ability of resisting the lateral loads during seismic events. It was also concluded that brick masonry has a greater effect on the seismic performance of a RC structure as compared to that of low strength concrete block masonry because of its greater strength and stiffness properties.

Keywords- Reinforced Concrete (RC), Infill Masonries, Seismic Performance, Response Spectrum Analysis (RSA).

1 INTRODUCTION

From the past few years, a practice of constructing reinforced concrete (RC) frame structures is being followed all over the world [1] especially in the Asian sub-continent, due to their functional efficiency and ease in construction. During the construction process, the frame elements (i.e. beams and columns) are constructed first and independently without any provision of infill walls. The open space left in between the frame elements is then filled up with unreinforced masonry that generally consists of either the brick masonry or low strength concrete block masonry. In the past, these infill masonries were considered as the non-structural elements of the building [1] (elements that do not contribute towards the load resisting ability of the structure) where they were supposed to fulfill two basic functions, first, to act as a divider for the division of interior spaces and second, as a protective shield against the effects of external environment i.e. snow, rain, wind, noise etc. But this is not the case now as the recent researches and studies have shown that they are no more the non-structural elements but greatly influence the overall performance of RC structures during the seismic activities. In the bare frame idealization of a RC structure, it is considered that infill masonries do not take part in load bearing process which may lead towards the overdesign of the structure as the presence of infill masonries in between the frame elements largely increases strength, stiffness and energy dissipation ability of RC structures during the seismic events. If the effect of infill masonries is incorporated into the seismic analysis of RC structures, it will lead to the design efficiency which may result in reducing the overall cost of the structures as they are already present in the structure and there will be no need to construct them separately like shear walls which are constructed in addition to the normal structural elements.

Similar works have also been made earlier to investigate the effect of infill masonries on the overall seismic performance of RC frame structures. Hr, Chidananda., Raghu, K., and Narayana, G., [2] after analyzing a fifteen storey (G +14) residential building had found out that maximum storey displacement and fundamental time period of RC structure were reduced by 51% and 46% respectively when the effect of infill masonry was considered in the seismic analysis of the given building. Strength and stiffness of an infilled frame RC structure were found to be 5.2 and 149 times greater than that of bare frame RC structures respectively in a research made by Haldar, P., and Singh, Y. [3]. Yousuf Dinar et. al. [4] as a result of a research on the seismic performance of bare frame and infilled frame RC structures had found out that increasing the percentage of infill increases the overall performance of RC structures against seismic activities. Raza, S., and Khan, M. K. I. [5] had found out that brick masonries are the best in the business during seismic activities, then comes the hollow concrete block masonries and solid concrete block masonries. Considering the work done by previous researchers and their future work recommendations, this research aims at the detailed evaluation and comparison of seismic performance of bare frame (BF), brick masonry infilled frame (BMIF) and low strength concrete block masonry infilled frame (CBMIF) RC structures. Prime objective of this research is to compare the seismic performance parameters like maximum storey displacement, maximum storey drift ratio, base shear, time period and overall stiffness of the BF, BMIF and CBMIF RC structures.

2 RESEARCH METHODOLOGY

For this research, a six storey (G +5) commercial building being located in Abbottabad was selected for the seismic evaluation as shown in Figure 1 (a) and (b). Three models of this building namely BF, BMIF and CBMIF were prepared in ETABS 2015. This modeling of the building involves two steps; first, the modeling of frame structure and second, the modeling of infill walls. A general modeling procedure was used for the modeling of frame structure whereas the modeling of infill walls was done according to the standard procedure of "equivalent diagonal strut method" as given in the section 7.5.2.1 of FEMA 356 [6]. According to this section of FEMA 356 [6], masonry infill walls should be replaced by a pin jointed equivalent diagonal strut of width "a", being provided between the two compression corners. The thickness and elastic modulus of which will be the same as that of infill wall whereas the length of it will be equal to the length of diagonal between the compression corners. According to FEMA 356 [6], the width of this strut "a" is given by:

$$a = \frac{0.175*D}{(\lambda_1*H)^{0.4}} \tag{1}$$

$$\lambda_1 = \left[\frac{E_m*t*Sin2\theta}{4*E_f*I_{col}*h}\right]^{0.25} \tag{2}$$

$$\theta = \tan^{-1}\left(\frac{h}{l}\right) \tag{3}$$

The strength and stiffness of a perforated panel is not the same as that of the completely infilled panel but varies in proportion with the percentage of openings. This change in strength and stiffness of a perforated panel is incorporated into the modeling as a reduction factor for percentage of openings (i.e. R_1). Al-Chaar [7] has explained this reduction factor in detail in his study. According to him, the reduced width of the strut "$a_{Reduced}$" is given by:

$$a_{Reduced} = a * R_1 \tag{4}$$

$$R_1 = 0.6 * \left(\frac{A_{openings}}{A_{panel}}\right)^2 - \left(1.6 * \frac{A_{openings}}{A_{panel}}\right) + 1 \tag{5}$$

In (1), (2), (3), (4) and (5), "D" is the length of diagonal between the two compression corners, "H" is height of infill between centerline of beams, "h" is clear height of infill, "t" is thickness of infill, "l" is clear length of infill, "I_{col}" is moment of inertia of column, "θ" is angle of inclination of strut with beam, "E_m" is elastic modulus of masonry "E_f" is elastic modulus of frame material, "λ_1" is the strut stiffness factor, "$A_{openings}$" is the area of openings whereas "A_{panel}" is the area of infill panel.

The modeling of infill walls as an equivalent diagonal strut was done in such a way that it was provided as a pin jointed zero weight or mass element between the two compression corners of the given frame of the given building. The effect of inertial mass of infill wall was incorporated into the analysis by assigning the whole mass of infill wall as a uniformly distributed load to the entire length of the beam upon which it was supposed to be resting.

a) b)

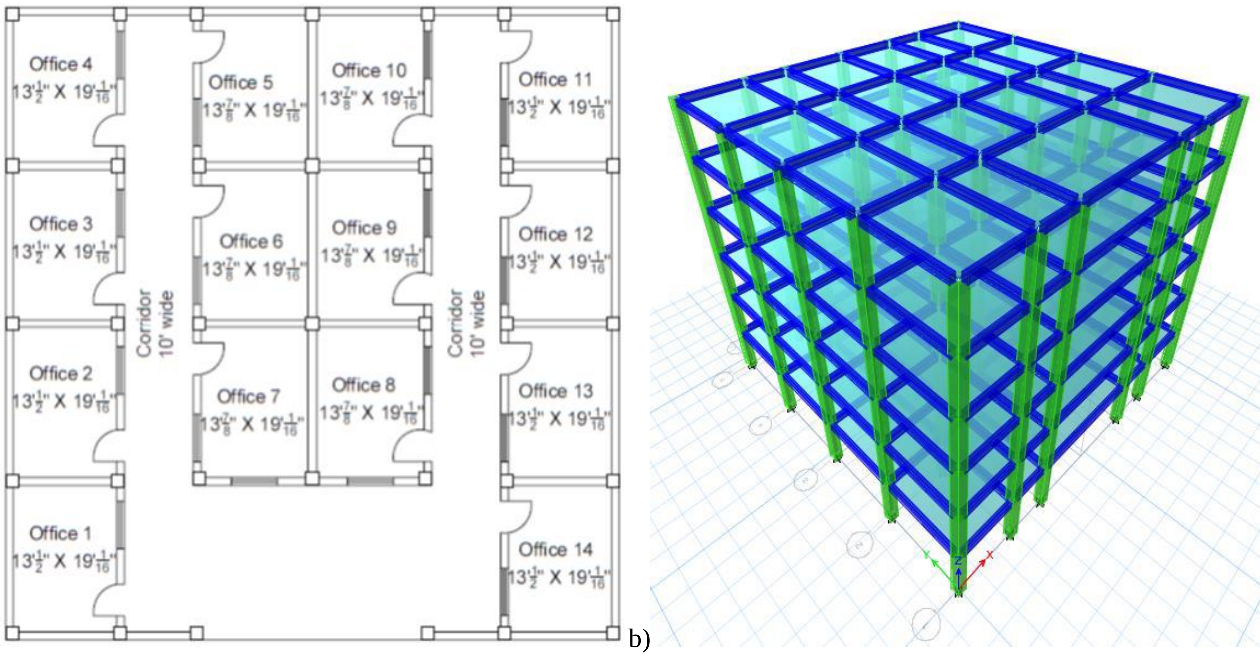


Figure 1: (a) Plan of Given Building, (b) Extruded BF 3D view of Building

Table 1: Building's Material Properties

Material Type	E	ν	Unit Weight	Design Strengths
	(psi)		**(pcf)**	**(ksi)**
Concrete	3604997	0.20	150	$f'_c=4$
Rebar/Steel	29000000	0.30	490	$F_y=60$; $F_u=90$
Bricks Masonry	410000	0.2383	120	$f'_m = 0.79$
Concrete Block Masonry	250000	0.3127	120	$f'_m = 0.40$

After the modeling, all the three models of given building were analyzed by linear dynamic method of seismic analysis i.e. RSA to get an insight into the dynamic behavior of the building. The seismic performance of all these models was then evaluated and compared on the basis of maximum storey displacement, maximum storey drift ratio, base shear, time period and overall stiffness of the structure.

Table 2**:** Building's Section Properties

Section Type	Size	Material	Shape
	(in)		
Beam	12" X18"	Reinforced Concrete	Rectangular

Column	18" X 18"	Reinforced Concrete	Rectangular
Slab	7" Thick	Reinforced Concrete	Shell Thin

Table 3: Summary of Loads on the Building

Load Type	Load Concentration		Description
	Storey 1 - Storey 5	**Storey 6**	
Dead Load	-	-	Self-Weight
Live Load	60 psf	40 psf	-
Superimposed Dead Load	43.75 psf	60 psf	Mortar (3") + Tiles (1")
Masonry Load	1 K/ft	0.15 K/ft	Main walls Load on Beam
Masonry Load	21 psf	21 psf	Partition Walls load on Slab
Earthquake Load	BCP 2007	BCP 2007	-

3 RESULTS

After analyzing all the three models of given building, their performance was evaluated on the basis of five parameters i.e. maximum storey displacement, maximum storey drift ratio, base shear, time period and overall stiffness of the structure. The comparison was made on the basis of maximum response of the building against each of these parameters. A brief overview of the results obtained from RSA of the given building is given as under:

3.1 Maximum Storey Displacement

Displacement is an important factor to be considered, when a structure gets hit by a seismic event. It mainly depends on the stiffness of the structure, greater the stiffness lesser will be the displacement produced in the building and vice versa. From the results obtained by RSA, maximum storey displacement was observed to be reduced by 69% in case of CBMIF whereas 79% in case of BMIF. This greater reduction of displacement in case of brick masonry was observed due to its greater stiffness as compared to that CBMIF.

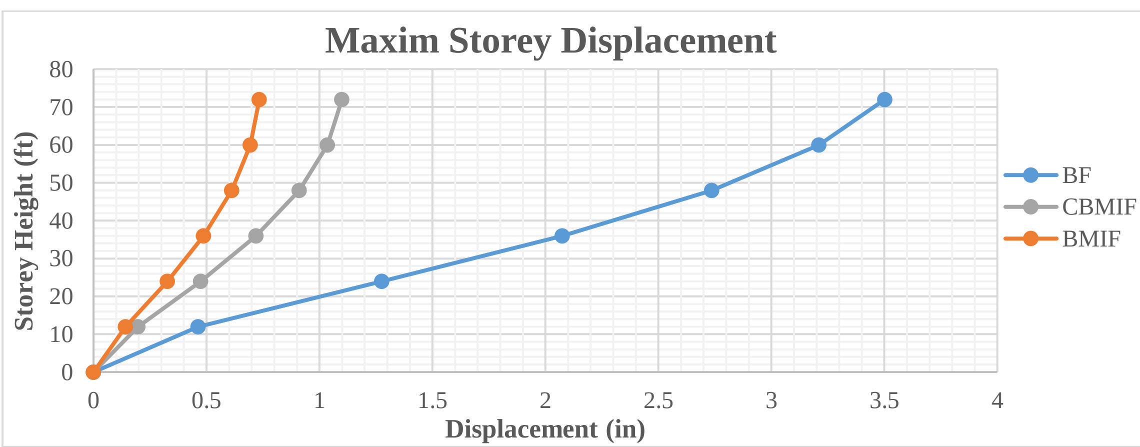


Figure 2: Comparison of Maximum Storey Displacement

3.2 Maximum Storey Drift Ratio

Storey drift ratio is the ratio of relative displacement between the adjacent stories to the storey height. It measures the displacement changing characteristics of a building; gradual changing characteristics ensure structural stability, uniform stiffness and less probability of structure getting damaged. From the results obtained by RSA, maximum storey drift ratio was observed to be reduced by 79% in case of CBMIF whereas 88% in case of BMIF. This greater reduction of storey drift ratio in case of brick masonry was observed due to its greater stiffness as compared to that of CBMIF.

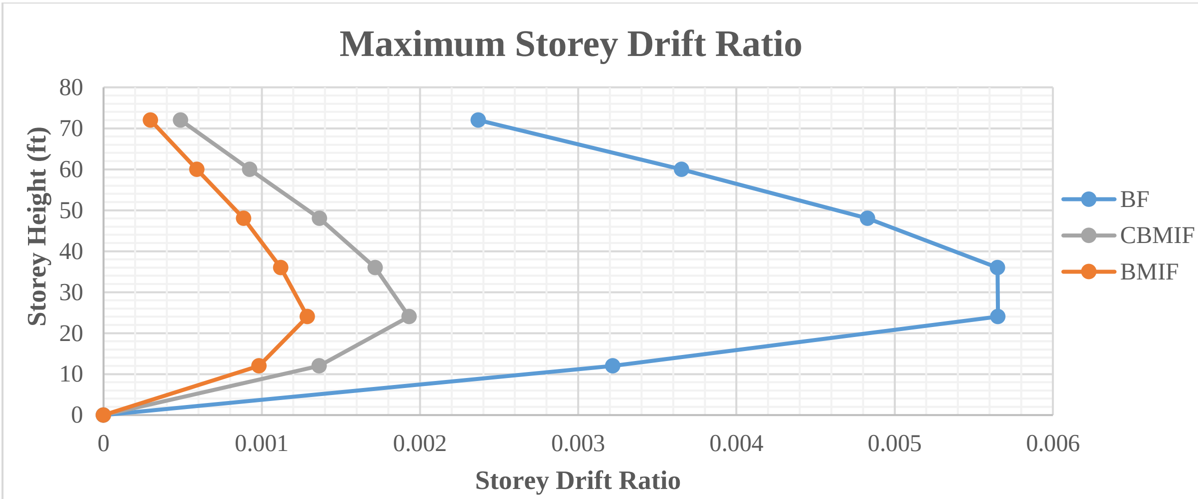


Figure 3: Comparison of Maximum storey Drift Ratio

3.3 Stiffness

Stiffness refers to the rigidity of a structure which means extent to which it can resist deformation under the application of a lateral load. Stiffness of a RC frame structure depends on the stiffness of individual structural elements, their concentration and orientation in the structure. Stiffness of individual elements on the other hand depends on their material and geometric properties i.e. modulus of elasticity and moment of inertia. Greater the elastic modulus or moment of inertia of an element, greater will be its stiffness resulting in increase of overall stiffness of the structure. From the results obtained by RSA, overall stiffness of the structure was observed to be increased by 238% in case of CBMIF whereas 413% in case of BMIF. This greater increase of overall stiffness in case of BMIF was observed due to its greater elastic modulus as compared to that of CBMIF.

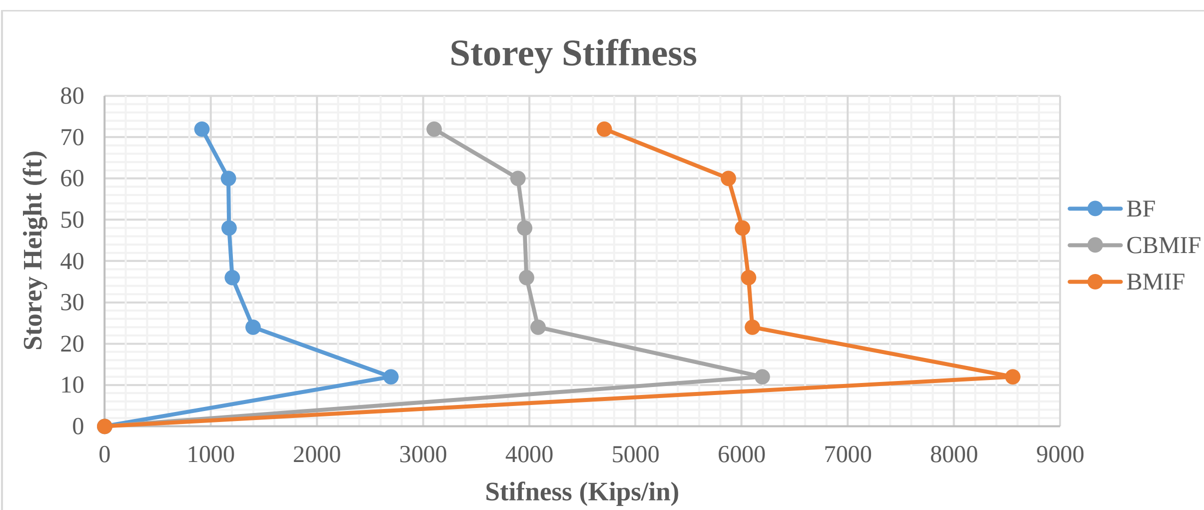


Figure 4: Comparison of Storey Stiffness

3.4 Base Shear

Base shear is an estimate of maximum anticipated sideways forces at the base of the structure as a result of a seismic event. Base shear generally depends on weight of the structure, stiffness of the structure and site characteristics of the structure.

For the structures having equal weight and similar site characteristics, stiffness is the ultimate parameter that base shear depends on. Flexible structures usually have lesser base shear as compared to stiffer ones. Base shear of all the three models considered in the research was found to be approximately the same because the analysis was terminated at same termination condition i.e. when dynamic base shear becomes greater than or equal to 85% of the static base shear. Therefore, base shear was expressed in terms of its scale factor for the sake of making comparison. Greater scale factor represents lesser base shear. From the results obtained by RSA, base shear was observed to be increased by 43% in case of CBMIF whereas 53% in case of BMIF. This greater increase of base shear in case of BMIF was observed due to its greater stiffness as compared to that of CBMIF.

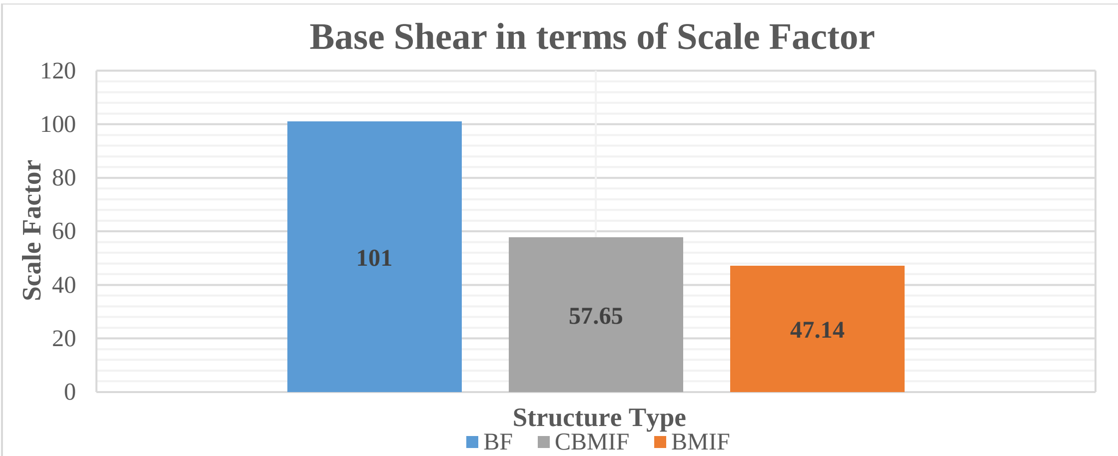


Figure 6: Comparison of Base Shear in terms of Scale Factor

3.5 Time Period

Time period of a structure is the time that it takes for each complete cycle of oscillation when hit by a seismic event. It is the inherent property of the structure that generally depends on mass and stiffness of the structure. For the structures of equal mass, stiffness is the only parameter determining the fundamental time period of the structure. Greater the stiffness of the structure, lesser will be its time period and vice versa. From the results obtained by RSA, time period of the structure was observed to be reduced by 39% in case of CBMIF whereas 51% in case of BMIF. This greater reduction of time period in case of BMIF was observed due to its greater stiffness as compared to that of CBMIF.

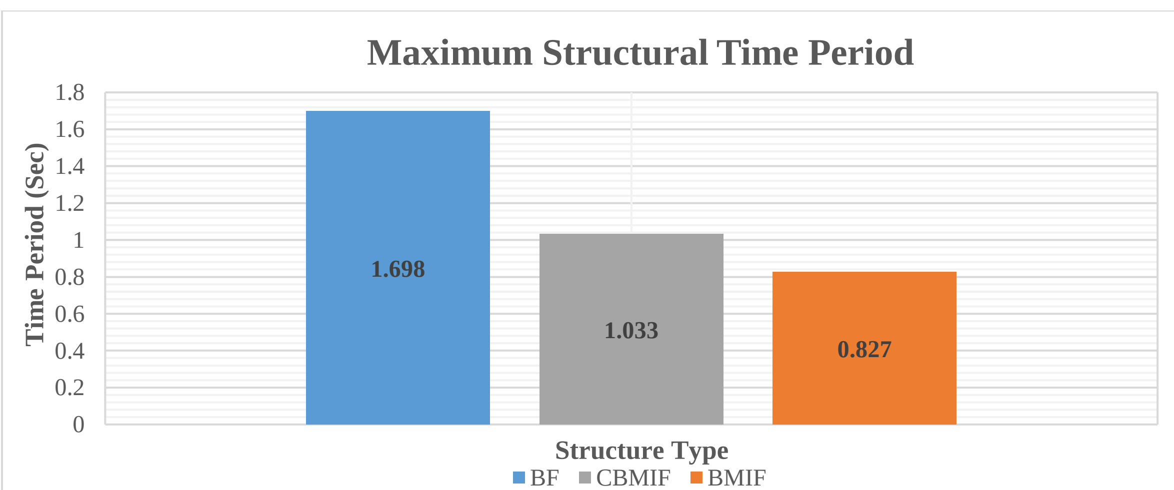


Figure 7: Comparison of Maximum Structural Time Period (Computational Model)

Building code of Pakistan (BCP 2007 [8]) also provides empirical relationships for the determination of fundamental time period of the building. According to BCP 2007 [8] time period of a building can be calculated by using (6), where H is the height, C_t is a coefficient (0.03 for bare frame and 0.02 for all other RC frame structures) and T is the fundamental time period of the building. From the results obtained by empirical formulae, time period of the structure was observed to be reduced by 33% when the effect of infill masonries was incorporated into the analysis. A comparison between the time period obtained from computational model and empirical formulae is also made in table 4.

$$T = C_t * H^{0.75} \tag{6}$$

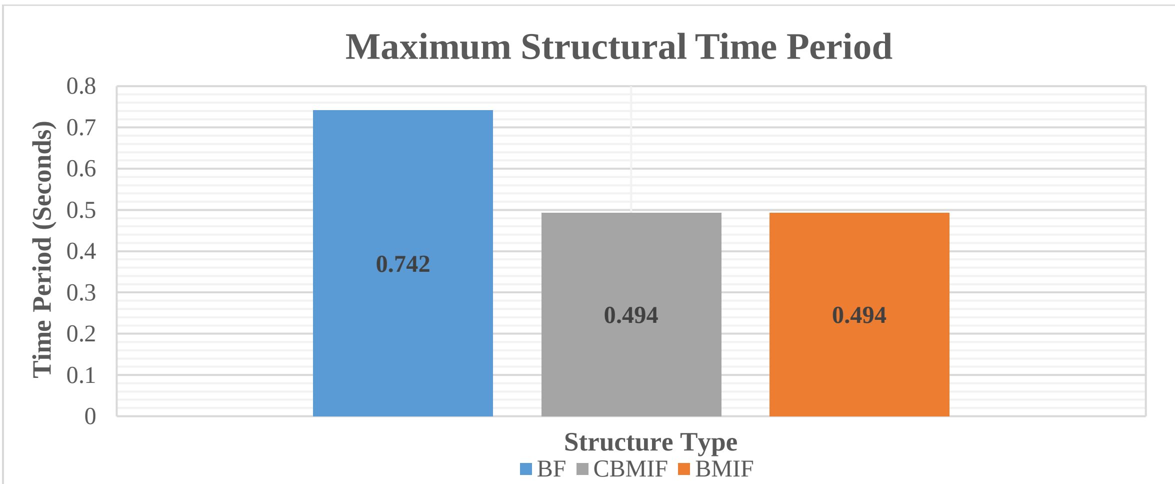


Figure 8: Comparison of Maximum Structural Time Period (Empirical Formulae)

Table 4: Comparison of Time Period Obtained from Computational Model and Empirical Formulae

	Time Period			
Structure Type	**Empirical Formulae**	**Computational Model**	**Increase**	**% Increase**
	(Sec)	**(Sec)**	**(Sec)**	
BF	0.742	1.698	0.956	128.8409704
CBMIF	0.494	1.033	0.539	109.1093117
BMIF	0.494	0.827	0.333	67.40890688

4 CONCLUSION

From the findings of this research, following conclusions can be drawn:

- Presence of infill masonries greatly improves the overall seismic performance of RC frame structures by increasing their strength, stiffness and ability of resisting the lateral loads during seismic events.
- Maximum storey displacement, maximum storey drift ratio and time period can be reduced whereas base shear and overall stiffness can be increased significantly by considering the effect of masonry infill walls in the seismic analysis of RC frame structures.
- Incorporating the effect of masonry infill walls into the seismic analysis of RC frame structures lead to the design efficiency which may result in reducing the overall cost of the structures.
- Brick masonry can be considered as the best in the business among the two masonry types considered in the study during seismic events due to its greater strength and stiffness properties.

On the basis results of this research, future works are recommended on this topic in order to develop detailed guidelines for the analysis and design of RC frame structures with infill masonries.

ACKNOWLEDGMENT

The authors would like to thank everyone who helped us to carry out this research, particularly Department of Civil Engineering, CUI, Abbottabad Campus. The authors also like to express special thanks of gratitude to the research supervisor Engr. Asif Shahzad and co-supervisor Engr. Tayyaba Bibi for providing their invaluable guidance throughout the research. Their dynamism, vision, sincerity and motivation have deeply inspired us.

REFERENCES

[1] S. Sattar and A. B. Liel, "SEISMIC PERFORMANCE OF REINFORCED CONCRETE FRAME STRUCTURES WITH AND WITHOUT MASONRY INFILL WALLS," *9th US National and 10th Canadian Conference on earthquake engineering.,* p. 10, 2010.

[2] . C. H., "ANALYSIS OF RC FRAMED STRUCTURES WITH CENTRAL AND PARTIAL OPENINGS IN MASONRY INFILL WALL USING DIAGONAL STRUT METHOD," *Int. J. Res. Eng. Technol.*, vol. 04, no. 04, pp. 640–647, Apr. 2015, doi: 10.15623/ijret.2015.0404110.

[3] P. Haldar, "Modeling of URM Infills and Their Effect on Seismic Behavior of RC Frame Buildings," *Open Constr. Build. Technol. J.*, vol. 6, no. 1, pp. 35–41, Oct. 2012, doi: 10.2174/1874836801206010035.

[4] Y. Dinar, Md. I. Hossain, R. Kumar Biswas, and Md. Masud Rana, "Descriptive Study of Pushover Analysis in RCC Structures of Rigid Joint," *IOSR J. Mech. Civ. Eng.*, vol. 11, no. 1, pp. 60–68, 2014, doi: 10.9790/1684-11126068.

[5] S. Raza and M. K. I. Khan, "Seismic vulnerability assessment of bare and masonry infilled reinforced concrete frame structures," *Int. J. Civ. Struct. Eng.*

[6] "FEMA 356 Prestandard and Commentary for the Seismic Rehabilitation of Buildings," p. 519, 2000.

[7] G. Al-Chaar, "Evaluating Strength and Stiffness of Unreinforced Masonry Infill Structures" Defense Technical Information Center, Fort Belvoir, VA, Jan. 2002. doi: 10.21236/ADA407072.

[8] "Building Code of Pakistan (Seismic Provisions 2007)," *Ministry of Housing and Works.*

ONE PART GEOPOLYMER USING RICE HUSK ASH AND METAKAOLIN

[a] Ammar Iqtidar, [b] Muhammad Faisal Javed, [c] Umer Khurshid, [d] Jawad Ihsaan, [e] Hadi Kamal
a: Department of Civil Engineering, COMSATS University Islamabad Abbottabad Campus, ammariqtidar@gmail.com
b: Department of Civil Engineering, COMSATS University Islamabad Abbottabad Campus, arbabfaisal@cuiatd.edu.pk
c: Department of Civil Engineering, COMSATS University Islamabad Abbottabad Campus, umerkhurshidkj@gmail.com
d: Department of Civil Engineering, COMSATS University Islamabad Abbottabad Campus, jawadihsan20@gmail.com
e: Department of Civil Engineering, COMSATS University Islamabad Abbottabad Campus, hadikamal777@gmail.com

Abstract- This research is conducted to assess the compressive strength of one part geopolymer mortar containing rice husk ash (RHA) and metakaolin (MK). Sodium Silicate in powder form is used as activator for the geopolymer. Water to binder ratio is kept constant at 0.5 for each sample. Two percent super plasticizer by weight of binder is added in mortar mix. The strengths of GM samples with different RHA/MK mass ratios are tested on 7, 14, and 28 days. The casted samples are placed in oven at 70°C for first 24 hours and then at ambient temperature of 19°C for rest of the time, till testing. Compressive strength of RHA/MK mass ratio of 10/90 is highest among all mixes. It is found that increasing the RHA more than 10 percent, results in reduced compressive strength.

Keywords- Geopolymer Mortar (GM), Metakaolin (MK)**,** One Part Geopolymer, Rice Husk Ash (RHA)

1 INTRODUCTION

Concrete is the second largest used material in world after water. Its constituents such as cement requires higher amount of energy to be prepared, this energy is obtained by burning fossil fuels. Along this, the hydration reaction of cement with water during preparation of concrete is an exothermic process and it releases energy in form of heat into the environment while forming bonds [1]. These two are the main reasons that contribute towards a great carbon footprint of concrete. About 9 percent of carbon dioxide in environment is due to manufacturing or use of concrete and its constituents [2]. So, attempts are being made to produce greener concrete with lowest carbon footprint and highest strength and sustainability. One of these attempts is to make green concrete using geopolymer (GP) materials available abundantly throughout the globe. Mainly the materials having properties same as cement are used for this purpose, called supplementary cementitious materials (SCMs). The SCMs include RHA, Ground Granulated Blast Furnace Slag (GGBFS), Fly Ash (FA), Condensed Silica Fumes (CSF) and various other industrial and agricultural wastes that are rich in silica and alumina [3].

While Pakistan is an agricultural country and produces tons of agricultural wastes annually, the use of these agricultural wastes by incorporating them in concrete can be taken into consideration. Pakistan produces 6.7 million tons of rice husks (RH) every year, as of year 2017, as rice is one of its major consumed and cash crops [4]. These RH are used as a fuel for boiling rice paddy in rice mills. The ash obtained from burning RH, known as rice husk ash (RHA), is then discarded into open environment or rivers which causes ground, air and water pollution. RHA is one of the SCMs that contains more than 90 percent silica. RHA when mixed with other materials such as GGBFS, FA in the presence of alkaline activators yields strength higher than that of normal OPC [5],[6]. RHA, containing silica, alone cannot replicate the properties of cement so an alumina source is also needed. Metakaolin (MK) contains considerable amount of alumina [7]. When inert Kaolin (KN) is calcined at elevated temperature then reactive metakaolin is formed. Several researches have been conducted which have shown that metakaolin can be used effectively with a silica source to replicate the properties of cement by the process of geopolymerization [8].

In this study RHA is used with MK to synthesize one part GP and then its strength is assessed. The use of GP based mortar utilizes the wastes of agricultural industry and consumes less energy as compared to the preparation of OPC. It results in reducing the depletion of natural resources that are used in manufacturing of OPC, as well as environmental pollution is also reduced which is caused by dumping RHA openly and a sustainable environment is created due to lesser emission of carbon dioxide.

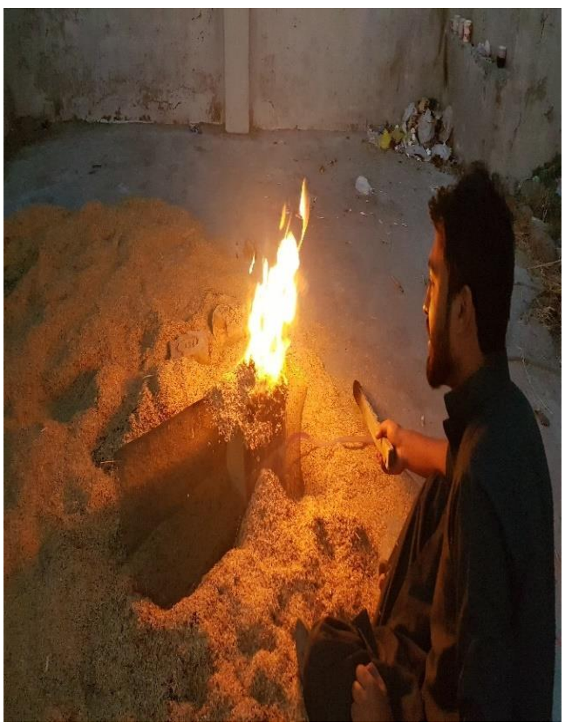
2 EXPERIMENTAL DETAILS AND RESEARCH METHODOLOGY

2.1 Raw Materials

For research purposes, the raw materials are collected from nearby markets. RH (Figure 1a) are easily available on hay stocks that spread throughout the Hazara Region. KN (Figure 1b) is available in different qualities in small industrial area of Mansehra namely, single washed KN and double washed KN. Single washed KN contains more impurities than double washed KN, so double washed KN is acquired. This KN is calcined to obtain MK. MK along with RHA is used for making GP mortar. Since this research is focused on one-part GP, so sodium silicate is obtained in powder form from a vendor. Sand used in this research is obtained from Havelian sand quarry.

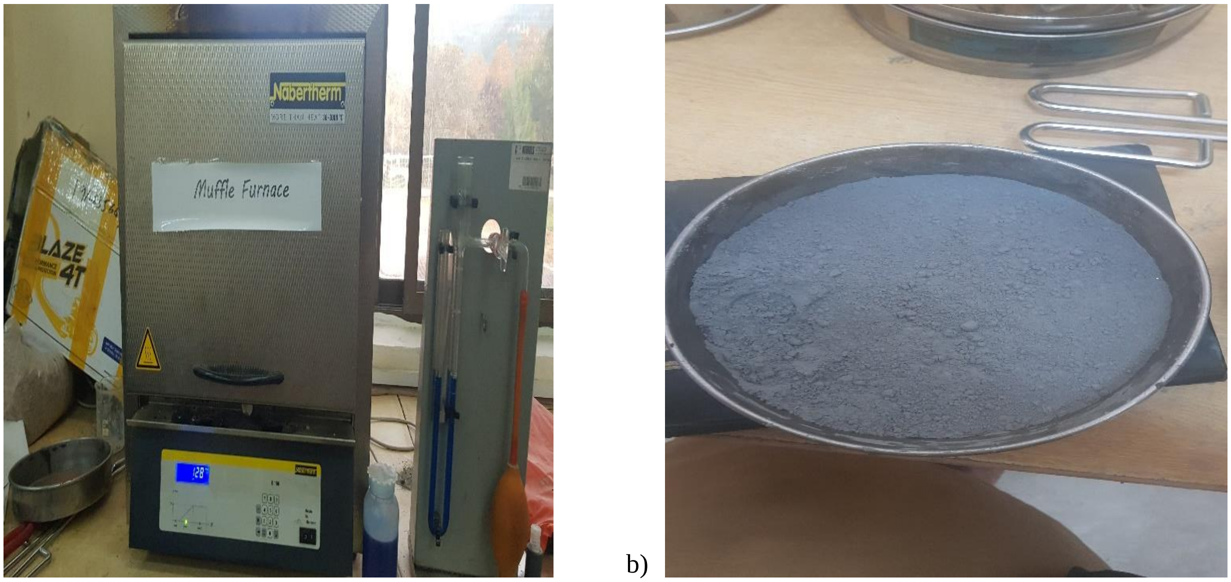
2.2 Raw Materials Processing

Rice Husks are first burnt in an uncontrolled environment. It helped in shrinking down the mass of RH. But the RHA obtained from uncontrolled burning is black in colour. The RHA obtained from uncontrolled burning is burnt under controlled temperatures in muffle furnace at 750°C for 3 hours for elimination of carbon. The resulting RHA is white in colour. The larger chunks of white KN are first broken into smaller pieces with hammer and then calcined in muffle furnace at 750°C for 6 hours (Figure 2a). The resulting MK is light brown in color. The RHA (Figure 2b) and MK are then separately grinded in roller jar mill. Then the grinded materials are passed through ASTM sieve number 200 and stored in air-tight bags, to prevent the materials from absorbing any moisture from atmosphere.

a) 

b) 

Figure 2: Raw materials, a. rice husks and b. kaolin



a) b)

Figure 2: Raw materials processing, a. kaolin being calcined and b. grinded RHA

2.3 Mixing, Casting and Testing

After acquiring the desired materials for GP, a mix design is necessary to prepare the GP mortar. As both MK and RHA are high water absorbing materials so the water to binder ratio is set by hit and trial method. Mass batching is selected as the suitable batching technique for this research. After that, the mass of dry mix is determined for making three GP cubes in 5.08×5.08×5.08-cm mold. It is found out that a dry mass of 800 grams is suffice for preparing six mortar cubes for the afore-mentioned mold size. The binder to sand ratio is kept constant as 1:1. Table 1 represents only the 50 percent constituents of GP mortar, that is, binder only. The rest of 50 percent is sand. RHA, MK, Sodium Silicate and Sand are added and mixed in dry form with the help of cobalt mixture for 5 minutes on low speed. Then water is sprinkled slowly on the mix while mixture kept rotating. Super plasticizer is added after water and mixture speed is set at high for another two minutes. A homogenous GP mortar is obtained. Moulds are lubricated with oil and assembled. Then the GP mortar is added in moulds in three layers with 25 blows on each layer with a pastel. The surfaces of cubes are made even with a cutter. The moulds are kept in oven for 24 hours at 70°C. Then the mortar cubes are demolded and kept at ambient temperature of 19°C for 7,14 and 28 days till testing. The compressive strength of cubes is tested by universal testing machine according to ASTM C109. A total of 9 cubes are prepared for each GP mortar sample (3 cubes are tested for each curing age, for example, for determining the 7 days compressive strength of R10M90, 3 cubes are tested by universal testing machine and their average is taken). So, for 3 samples a total of 27 GP mortar cubes are prepared. And for Ordinary Portland Cement (OPC), 9 cubes are prepared separately.

Table 5- Mix design of GP mortar

Sample ID	RHA (% of mass of binder)	MK (% of mass of binder)	OPC (% of mass of binder)	Water to Binder Ratio	Super-plasticizer (% of mass of binder)
R10M90	10	90	0	0.5	2
R20M80	20	80	0	0.5	2
R90M10	90	10	0	0.5	2
OPC	0	0	100	0.5	-

3 RESULTS

The results of compressive strength on different curing age are shown in table 2. For each curing age three cubes are tested. The average of three compressive strengths is calculated and presented as the compressive strength of that single day. The table shows vigorous increase of compressive strength till 7 days and then the compressive strength keeps increasing gradually till 28 days. The 28th day strength is the maximum of all. The results show that R10M90 imparts greatest compressive strength of all mixes. However, by increasing the amount of RHA to 20 percent, the compressive strength is reduced as compared to R10M90. If quantity of RHA is increased to 90 percent, the compressive strength gets affected much adversely. It can be seen in the table below that 7, 14 and 28 days compressive strength of R10M90 is 48,53 and 64 percent, respectively, more than that of OPC sample. The highest compressive strength is also shown by R10M90 at 28 days, that is 21.05 MPa. The main reason for increase in compressive strength is due to bonds present between Silica of RHA and Alumina of MK, which represent the properties of geopolymers.

Table 2- Difference in compressive strength as compared to OPC

Sample ID	Compressive strength at different curing ages (MPa)						
	7 Days	**Difference in compressive strength as compared to OPC (%)**	**14 Days**	**Difference in compressive strength as compared to OPC (%)**	**28 Days**	**Difference in compressive strength as compared to OPC (%)**	**Standard Deviation (For three GP mortar samples)**
R10M90	17.56	48.18	19.26	53.34	21.05	64.45	7.19 (28 days)
R20M80	15.25	28.70	16.86	34.23	17.65	37.89	6.67 (14 days)
R90M10	04.82	-59.32	06.70	-46.65	07.25	-43.35	6.78 (7 days)
OPC	11.85	-	12.56	-	12.80	-	-

Table 2 represents the difference of compressive strengths between GP mortars and OPC mortar. It can be noted that two GP mortar samples R10M90 and R20M90 have greater strength than OPC mortar at 7, 14 and 28 days. While R90M10 GP mortar sample has less strength than that of OPC at all days. The negative sign (-) for R90M10 in strength difference columns represents that this GP mortar has strength less than that of OPC.

4 CONCLUSION

Following conclusions can be drawn from the conducted study:

- One part geopolymers can be made successfully by incorporating RHA and metakaolin.
- Maximum compressive strength can be achieved by using 10 percent RHA and 90 percent metakaolin in one part geopolymers.
- RHA quantities more than 10 percent results in decrease in compressive strength, when used with metakaolin.

The above outcome is favorable indicating the one part GPs can be synthesized successfully in Pakistan. The next step should be to make concrete from this one part GP, having higher compressive strength and higher durability. The chemical activator source should be replaced with the one found in nature.

REFERENCES

[1] C. R. Gagg, “Cement and concrete as an engineering material: An historic appraisal and case study analysis,” *Engineering Failure Analysis*, vol. 40, pp. 114–140, 2014.

[2] Y. Geng, Z. Wang, L. Shen, and J. Zhao, “Calculating of CO2 emission factors for Chinese cement production based on inorganic carbon and organic carbon,” *Journal of Cleaner Production*, vol. 217, pp. 503–509, 2019.

[3] A. Mehta and R. Siddique, “An overview of geopolymers derived from industrial by-products,” *Construction and Building Materials*, vol. 127, pp. 183–198, 2016.

[4] A. Raza, "Pakistan: Grain and Feed Annual," *USDA Foreign Agricultural Service: Washington, DC, USA*, vol 12, pp. 5-8, 2017.

[5] A. Mehta and R. Siddique, “Sustainable geopolymer concrete using ground granulated blast furnace slag and rice husk ash: Strength and permeability properties,” *Journal of Cleaner Production*, vol. 205, pp. 49–57, 2018.

[6] Zhu, Huajun, G. Liang, J. Xu, Q. Wu, and M. Zhai. "Influence of rice husk ash on the waterproof properties of ultrafine fly ash based geopolymer." *Construction and Building Materials,* vol. 208, pp. 394-401,2019

[7] Z. Li, S. Zhang, Y. Zuo, W. Chen, and G. Ye, “Chemical deformation of metakaolin based geopolymer,” *Cement and Concrete Research*, vol. 120, pp. 108–118, 2019.

[8] Liang, Guangwei, H. Zhu, Z. Zhang, and Q. Wu. "Effect of rice husk ash addition on the compressive strength and thermal stability of metakaolin based geopolymer." *Construction and Building Materials,* vol 222, pp. 872-881, 2019.

STUDYING BEHAVIOUR OF FIBRE REINFORCED COMPOSITES USING SCANNING ELECTRON MICROSCOPY ANALYSIS - A REVIEW

[a] Safeer Ullah
a: Department of Civil Engineering, CUI, Abbottabad Campus. safeer@cuiatd.edu.pk

Abstract- The microscope has been a versatile tool in the study of cementitious composites since the development of these materials. The scanning electron microscope (SEM) is one of the most developmental instruments available for the analysis and examination of morphological characteristics of fibre and its matrixes. This paper gives a brief review of the accuracy of scanning electron microscopy method for understanding performance of fibre reinforced composites and prediction of behavior of fibrous concrete. It also focuses on the scope of the scanning electron microscopy (SEM) method in the near future in fields fibre reinforced concrete research work. Selected researches of SEM usage in FRC have also been discussed. The electron microscopy is used as an investigation instrument in understanding the potential of the varying behavior of different fibrous composites at different conditions, an investigation mechanism in making suitable matrix, and a diagnosis equipment on problems like cracking. The paper also investigated how microstructural analysis reveal the expected mechanical behavior.

Keywords- FRC, Performance of Fibrous Composites, Scanning Electron Microscopy.

1 INTRODUCTION

The use of SEM studies in recent years has become increasingly popular in concrete studies, similarly this approach remains important in the study of fibrous composites for many civil engineers. The importance of the versatile method is further incorporated as an electron microscopy [1]. An electron microscope equipped with an X-ray spectrometer for diffusion energy can entertain very useful interpretations in analyzing concrete problems with high resolution images such as alkali-aggregate reactions in aggregates [2]. The performance of high-performance concrete cannot be adequately evaluated without examining the features of interfacial microlevel analysis of high-performance concrete, as seen under SEM [3]. As the use of electronic microscopy is becoming more expensive, there is a chance that the process will be widely used and understood [4]. This understanding of the underlying mechanism, the opportunities it provides for understanding the behavior of fibrous composites and analyzing integrated fiber problems, and strives for a recommended opportunity in experimental programs where intensive studies can make good output from SEM.

Microscale surface morphology analysis of the tested FRC samples can be easily revealed by SEM observations. To have reliable information about the microstructure, a large number of images were collected and analyzed for various microscale studies using a scanning microscope of mixed fibrous concrete containing fly ash and bottom ash [5]. It was concluded from the SEM experiment that when mixing the concrete, this light, C-S-H gel, covered the top surface of the concrete. This confirms that the C-S-H gel acts as a major handle on the concrete core to achieve the required strength, which is in consistent with the results in previous studies. [6]. The morphological analysis such as interfacial bonding, dilation of the matrix, fibre pulling or fracture between the fibre and matrix in treated and pretreated condition was studies in the composites are examined and analyzed using SEM analysis [7]. The investigation of thermal properties hybrid fibrous composites and its effects of chemical treatment was found using Thermogravimetric analysis (TGA), Dynamic Mechanical Analysis (DMA) and differential scanning calorimetry (DSC) and the correlation of change in fibre morphology was verified by SEM analysis [8].

In early 80s, SEM image analysis was used to study the surface morphology and fracture pattern during cracking. The separation of cracks, branching and the debonding of interface provide energy absorbing capacity of the steel fibre composite. This energy absorption was verified as additional effect to fibre pull out [9]. SEM analysis of broken specimens of shear and compression shows a considerable difference in the fibre-cement transition. For un-aged fibrous composites, the transition zone around the fibres was open and having gaps and microcracks, and this was accompanied by a greater fibre pull out in contrast to fibre exposed to natural aging and carbonation. [10]. SEM analysis of Chemically Treated and untreated coir fibre micromorphology have shown different characteristics i.e. the former has partially split unit cells due to removal of wax and larger pits and the latter have uniform unit cell and shallow cavities due to lignin and fatty substances. and mechanical results are verified by the evidence of SEM observations. [11]. Carbon nano fibre and nano materials significantly increase the mechanical performance of concrete. [12] observation of cracked surface in glass fibre reinforced cement revealed the effect of aging on the pull out of fibre from the matric during fractures. The images obtained showed how the surface were modified and increased pull out of fibre from the matrix. [13] The plain-strain fracture test was conducted by applying load on the composite specimen on the y-axis in the direction of loading and causing the propagation of the crack and the ZX plane. Carbon fibers are likely to be attacked along the bead printing direction because of its behavioral characteristics. Therefore, in perpendicular samples, the associated fibers may not contribute much to the stiffness. Because of this, the inter-bead contributed negligently to the cracking conditions. In contrast, where the beads are aligned with the fracture plane and have contributed to the fracture elasticity. The fibers within the conventional overlap size should provide surface resistance So, a large amount of fiber resistance and uneven topography are expected from the surface of the perpendicular beam fractures. In the case of 45 oblique samples, both cracks contributed equally to the crack process during load application [14]. SEM analysis is crucial in fibre reinforced composites and to the best of author knowledge no research is done on revealing FRC behavior using SEM method. A systematic literature review of SEM analysis on durability of natural, synthetic and steel fibre will be helpful in the application of the fibres.

2 Scanning Electron Microscopy

The SEM is constructed of a high-resolution image with an electron optical strand that produces and concentrates the electron beam above the visible surface. An evenly sized plate eliminates the energy of the electrons that strike through a series of certain scattering events. In cement and concrete attachments this volume can be 2-3 microns in depth and width [15]. Scanning low-power electron from the upper parts of the chamber are reflected on the surface layer of the specimen. The complex comes from the applied industry and is a subtle signal that can be detected such as back electrons, secondary electrons and X-rays. The unchanged electrons have high potential as they are dispersed in the process depth and are measured by detectors and converted into high resolution images. Comparison of concentrated electronics is very efficient in detecting basic differences, often in material that is distorted, and topographical distortion can still be seen if the difference in the standard range is large [1]. The basic comparisons, in the case of compounds, are equal to the atomic number of substituted elements depending on their relative behavior [16].

2.1 Sample preparation

Optimizing the SEM view set in a separated and soft spot is easy by comparison. Paste at the beginning of 2 hours can be optimized for SEM observation [17]. High resolution images without polishing allow the examination and identification of crystals in cracked, aggregated surfaces that can be composed of polished plates [18]. Backscattered electron images in the molded area were particularly sensitive to unwanted changes in the sample in preparation. The sample structure can be stabilized by adding a low viscosity epoxy due to the Vacuum installation method, which is why the unwanted change can be reduced [19]. Some investigators consider that the invisible and open wire circuits of both scattered electrons and scattered back electrons give sufficient results when compared to embedded and polished epoxy samples [20]). For the preparation of both compacted and molded samples for SEM testing including pre-test suspension, this procedure may alter the microlevel coating surface and results in smaller cracks.

2.2 Image analysis

Backscattered electron Images make provision of examining the specific gravities of different phases at microlevel analysis directly. The characteristics of hitting of electrons scattered from a specimen locality on the sample surface solely depends on the structure and atomic/compound number of the material at that position. It was established to possibly categorized four stages: grains of un-hydrated cement takes shape as bright, pores black, other hydrated compounds darker grey and calcium hydroxide light grey [19]. The Backscattered electron Images examination process is developing and is mostly used together with other imaging investigation tools. SEM method has made elaboration to the systematic analysis of the different stages in cement composites with expanding refinements [21]. Voids in fibrous cement composites can be distinguished, with the help of high-resolution images in software analysis, with respect to absorption and porosity, grain sizes, distribution and their inter connectivity. [15]. Now, there is important progress on the hardware side, particularly in the environmental scanning electron microscope. Optimistically, this will mitigate the issues related to damages in sample during electron microscopy observations [22].

2.3 Usage of SEM

SEM have been used by many researchers in the field of concrete and cement composites, the detailed literature of the various applications is given below.

a. The aggregate/paste interface

The two-dimensional system of adhesion and bonding to concrete can be better understood by microstructure studies using SEM. The model for the relationship of porosity and tensile strength was also considered as a system for both coating and bonded surfaces [6]. The delicate center of the joint and the adhesive shown by its magnitude, have been considered as a weak concrete phase for some time. This is a sensitive, compound-bonded, repeatable C-S-H film [23]). The SEM studies of this crucial bonding in concrete are easily understood using high resolution images. The space between the adhesive particles in the concrete is almost up to 100 microns, while the average compaction area and the adhesive are about 50 microns. A thorough examination of this guide and how it can be modified or installed has greatly assisted in the construction of the concrete for the strength and desirable properties. [6].

b. Effects of various Admixtures on the microstructure and properties

The installation of various admixtures has always played critical role in the manufacturing of desirable concrete these days to enhance its efficiency, strength, durability, decrease in dampness and cracking. Upgraded and new admixtures are still required for desirable properties. Mineralogical admixtures such as fly ash and silica fume, are widely used in advanced and local concrete. The small effects of the admixtures structure cannot be ignored in different studies [16]. The incorporation of various mineral admixtures alters the properties of the surfaces through immersion pores and grains [24] .A convincing conclusion was drawn from research on the related effect of silica fume on concrete and adhesive, the supplement did not improve the adhesion strength, but the synthetic concrete was stronger than the adhesive [15].

c. Many sites practice

Higher elevated temperatures due to cement delivery, materials use, different handling or concrete than curing and concrete vibration techniques have an impact on concrete properties. [25] Redon and jean used SEM and other analyzes to determine the effect of the therapeutic regime on the concrete microstructure. It was confirmed that pre-treatment of the joints with cement-lubricant or sliding off of the fume reduced the absorption and durability of the adhesive and adhesive linings. Many studies have shown the improvement of the paste/aggregate surface by pretreatment of concrete constituent.

2.4 Concrete durability

Various investigators have studied the contribution and effects of other factors on the performance and durability of concrete, through SEM testing. This includes cracking results similar to those found in concrete with steam treatment [26]. Tightening the bonding and its strength at paste/aggregate zoning, and the importance of paste/ fine-aggregate interface instead of paste and coarse aggregate [27].

2.5 Output of SEM

SEM is important for developing our learning of the inner properties of concrete. Cement hydrated products are not only complex but also have structural importance [26]. Structurally, the paste contains crystalline, quasia-morphous and amorphous phases. In terms of particle size, the ratio is about the size of a micrometer. The particle assembly to form an adhesive micostorganist, on a micro-morphological scale, is in the tens or hundreds of micrometers. SEM has good solutions to these calculations and has been widely used in systematic studies. There was an increasing interest in concrete research in the 1970s. Cement concrete studies under SEM revealed "internal product" (cement hydration by the incorporation of water molecules into a waterproof concrete), and "external product" (made from finishing and burning without concrete)[28].

3 Scanning Electron Microscopy In Frc

The multidirectional divided and oblique cracks were initially studied in Steel fibre reinforced cement in SEM observation. The acetone and trichloroethane fibers of a smooth and clean surface were inspected under SEM chamber prior to loading [9]. The cracking pattern was also observed after the loading of the preferred behavior of the reaction coupled with the extreme adhesion of the cement paste to solid and solid steel. Internal recognition of the interface at the bottom of the frame indicates that the fracture mechanism in the matrix around the fiber is catastrophic, and in many cases, characterized by branches, sometimes terminated by the formation of small microcracks around the larger one. The effects of the chemical treatment on surface polypropylene fibers (PPF) and the relative strength of PPF reinforced concrete have been investigated by N. loavat et al. There were three treatment groups in this study, all containing polypropylene fibers, and a control group. The first and second treatments were performed by adding PPF to a solution of mild aleic acid and an alkaline solution of the B-H group respectively. Some failed samples were randomly selected and examined using the Scanning Electron Microscopy (SEM) method. This was used to investigate the characteristics of the optical interface between the concrete tray and the fiber surface. The polypropylene fibers failed to be deposited and gold was synthesized prior to SEM examination. Acid carbon atoms are attached to the surface of the PPF, forming an incomplete bond. This will render the earth inactive and in the surrounding matrix of the cement and consequently allow crystalline growth of hydrated materials in the form of Carbon-Hydrogen crystals on the fibre surface [29].

The effect of microstructures and the interface on cementitious materials made with steel slag were studied by yue et al. cotton-based resin and cotton-formaldehyde resin were added with iron slag and cement at 2: 3: 5. The strength, flexibility and durability was assessed after being immersed in a mixing water for 24 hours. Microscopic composition of the hydration products was observed with SEM. The analyzed images show that the insoluble fiber surface was smooth and the formaldehyde-coated surface was well integrated with a gel that sealed the gaps in the matrix, the mechanical strength increased by 18%, and the water resistance significantly improved, that is well in line with the physical characteristics of the microstructures and the study results show that urea formaldehyde resin and fiber treated have good adhesion properties[30]. Attempts were made by [31] geng and leon to connect the extracting the fiber from the matrix to the microstructure of the material and the matrix interface. The microstructural characteristics of fiber (steel, nylon and polypropylene) / matrix interface were examined during the fiber pull out and debonding process. Because the fiber output was found to be weak for subsequent compression, microlevel studies were performed on the frictional frames and lateral compression. SEM and energy-dispersive X-ray (EDX) analysis was performed in four different phases: (a) before debonding; (b) immediately after debonding; (c) smaller sliding distance; and (d) the greater sliding distance. It was found that the molding area was placed under tension, while the steel surface was placed under plastic deformation. As discussed in the SEM study, when applying lateral pressure to the mortar during pullout of fiber, the effect of abrasion has been much greater on the steel fibers.

Lu Shang et al [32] studied glass fiber reinforced cement composites (GFRCC) with Portland cement and high fly ash content as a matrix. AR glass fiber 12 mm long with 2% volume content was used as reinforcement. The effect of ash content, treatment duration, and accelerated aging on GFRCC were investigated. The addition of fly ash reduced the initial capacity in term of early strength of the GFRCC. The higher the fly ash content, the greater the reduction in strength from 7 to 28 days, flexural strength improved again, and continued to increase after 28 days. A very poorly damaged AR glass fiber in the Portland cement matrix without being filled with ash after 1 day of rapid acceleration in 80 ° C was observed using SEM. Glass fibers from a matrix containing 60% ash showed more smooth AR glass after 1 day of rapid aging. D.A. Silva [33] investigated the durability of reusable PET fibers with the material having properties as shown in Table No. 1, that were embedded in Portland cement materials. Two separate testing methods were approved to study the degradation of fibers in cement matrix. For the first time, the fragments were observed by infrared spectroscopy and scanning electron microscopy (SEM) after their exposure to solutions of alkaline substance. In the second process, a fiber-reinforced mortar model was created and tested to find other mechanical properties. Fibers are immersed in Ca (OH) saturated solution with a Lawrence solution for 150 days at 5, 25, and 50 C and then performed microscopy, revealing details on the materials used to produce the mud. Mud samples were molded and stored in lime water for two weeks prior to the laboratory description and at 42, 104, and 164 days of age, mortar indicators were evaluated for compression and tensile strength. The thicknesses of the matrix fragments obtained from the split tensile test were observed by scanning electron microscopy (SEM), in order to detect any evidence of deformation in the cement paste. the results were in line with previous findings on cement materials that used low volume PET fiber in cementitious composites. Figure 1 shows the micrograph inside the mix after 164 days. As can be seen, the surface of the fibers appears to be very hard, indicating that the fibers are attacked by something from the cement paste matrix. SEM micrographs allowed the interpretations of the rate of degradation of fibers within the membranes after 164 days. All the analyzed fibers showed some apparent corrosion. In some regions, complete destruction of the pieces of fiber may occur. The adaptive performance of cement mixtures involving low frequency cold plasma treated polypropylene (PP) was investigated in this study. The Potential physical changes in surface layers of the fiber were detected by scanning electron microscope (SEM) on micrometer scales. The experimental results have shown that normal plasma treatment conditions lead to improvement of toughness of PP fibres in the composites. From the SEM observations and measurements of wettability, it was argued that the main mechanism for improving performance was the result of an increase in adhesion between the PP and the matrix [34]. A. A. Ramezanianpour et all studied the effect of polypropylene fibers on permeability in concrete. Water penetration, ultrasonic, and sorptivity tests were performed in order to signify the effects of PPF on durability. The study of microstructures and interfacial transition zone reveal that PPF can possible minimize permeability and porosity by pore blocking [35]

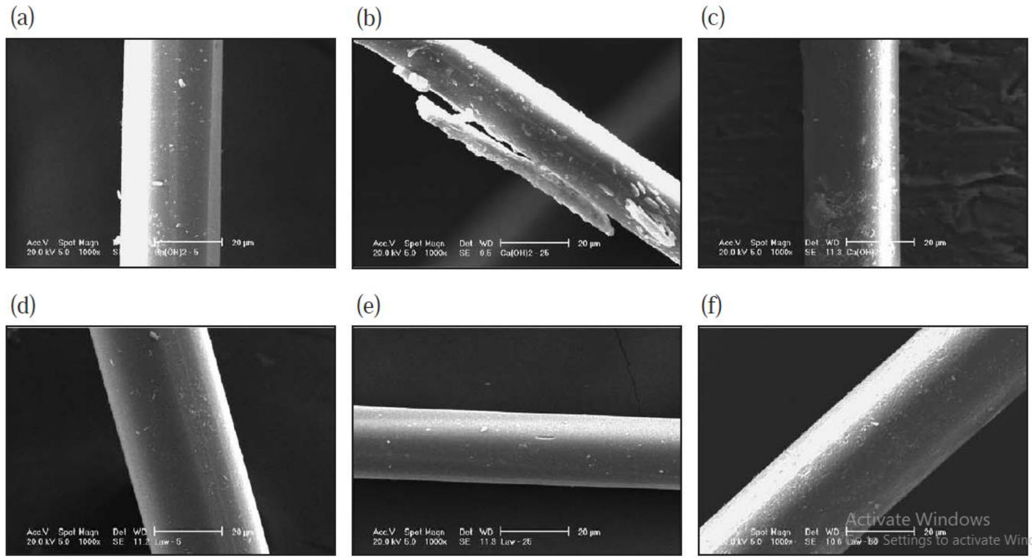


Figure 3. Micrographs showing the aspect of the PET fibres after 150 days of immersion in Ca(OH)2 solution at (a) 5C, (b) 25C, and (c) 50C, and in Lawrence solution at (d) 5C, (e) 25C, and (f) 50C [33].

F. Elgabas et al, experimentally studied that the physical, mechanical, and durability characteristics of basalt fiber-reinforced polymer (BFRP) bars. Three types of BFRP bars were investigated and Analyzed results postulated that the BFRP bars were of satisfactory performance and can be classified in the same general class as grade II and grade III GFRP (according to modulus of elasticity). The results confirm that the basalt fibers and resins used in this study were not affected by this condition. The deterioration of the strength seen in the BFRP bars was included in the fiber-matrix, which confirmed the poor bond between the resin and basalt fibers, as confirmed by SEM [36].

Table No 1. Characteristics of PET fibres[33]

Physical properties	Melting (C)	252.8
determined by DSC	Crystallization (C)	95
Mechanical properties	Strength (MPa)	323.5
	Elongation (%)	70.7
	Yield stress (MPa)	196
	Elongation (%)	7.18
	E (MPa)	41.0
	Toughness (MPa)	17279.0

Analysis of the morphological features before and after splitting tensile test was studied using scanning electron microscopy (SEM) technique to follow the failure examination in carbon fibre reinforced polymer (CFRP) and epoxy resins. SEM Micrograph analysis of the CFRP plate prior to the split test shows the presence of some manufacturing complexity and faults, which can alter the properties of the materials. Micrograph analysis after rigorous examination shows that the propagation of the crack begins in the zones nearest to production defects, which results in the pullout of carbon fiber rather than fracture. Thus, cracks propagate through the contact surfaces that affect the strength of the interaction between the matrix and the carbon fiber. For epoxy materials, microscopy experiments show that even though epoxies adhere to phase separation prior to complex experiments, the failure zone is defined by fine granular particles attached to the matrix, and the material fails aggressively when the force exceeds these bonds. The mechanism of failure of each element related to mechanical properties and the behavioral characteristics of the matrix was understood by SEM observation [37]. The cross section between FRP and substrate is reported to be the weakest link to other FRP reinforced systems, such as FRP-concrete and FRP steel system. Compared to the FRP-concrete and FRP-steel, these findings confirmed that the wood substrate is a more sensitive surface than the interface of the FRP wood system. The wood adjacent of the composite material deteriorated faster than the existing connection with heat exposure. Such information can advance understanding of the fire behavior of FRP and wood, and provide the basic details of fiber design, attachments or materials for combating firewood with better fire resistance[38]. M. Usman investigated the effect of natural weathering on prestressed concrete girder made with steel fibre reinforced concrete and polypropylene fibre reinforced concrete. The specimens were exposed to natural environment for 36 months. The durability properties were investigated, and SEM analysis was done. SEM microgram of steel fibres in confined environment are shown in figure 2(a), since the fibre were not exposed to natural environment and thus fibre are in normal condition and has no effect of rusting. The high-resolution SEM micrograph of the fibrous concrete exposed to natural environmental conditions are shown in figure 2(a) and figure 2(b). The effect of natural weather was examined in the area around the steel fibre (SF) and it was concluded that steel fibre were rusted and concrete was in normal condition. The more high-resolution image in figure 2(c) verified that steel fibre corroded due to rusting and this was happened due exposure to atmospheric condition [39].

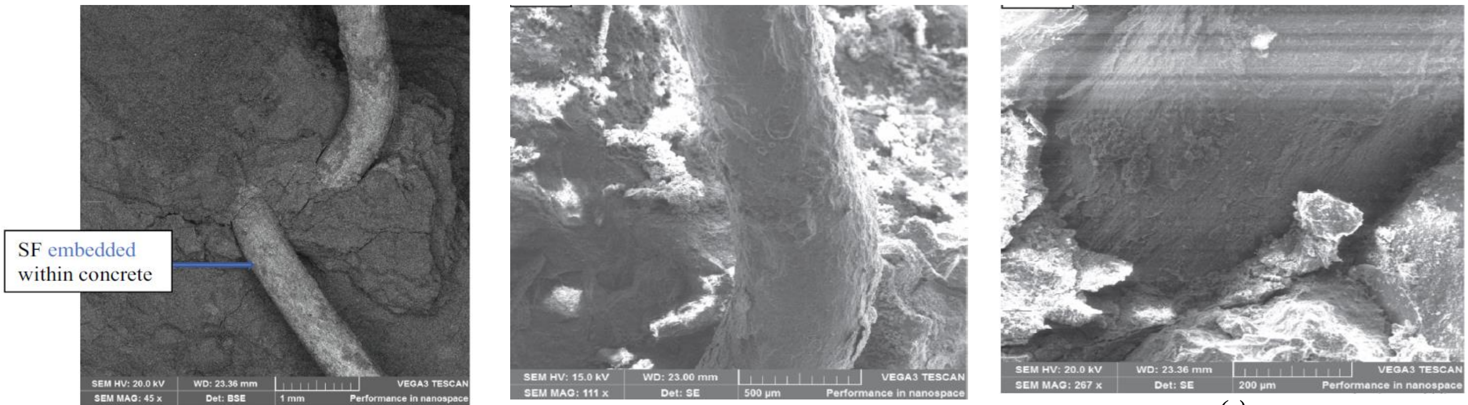


Figure 4. (a): Steel fibre embedded in concrete in confined condition, (b) and (c): Steel fibre in concrete exposed to natural weather conditions [39]

V. afroughsabet et al investigated properties of hybrid-fiber-reinforced concrete (HyFRC) constituted with expansive Type K cement and addition of fiber volume fraction of 1%. The microstructural and mechanical properties of steel double hook end (DHE), steel hook end (HE) and polyvinyl alcohol (PVA) fibrous composites were studied. The addition of type K cement improved volume stability at drying condition and enhanced pull out resistance of steel fiber by 26%. The SEM micrograph of fiber embedded in paste as shown in figure 3 were investigated. As shown in figure 3(a) on a fracture surface of matrix having 0.5% PVA fibres. A half embedded PVA fibre in matrix (solid square in red) and the other end of the fibre (red dashed square) shows large deformation, possibly this could be a fracture too. This indicated that a very well embedded PVA fibre in the mix increased resistance against cracking. In figure 3(b) a very tight bond between mix and fibre was observed and the mix was still tightly attached to steel fiber even after fracture. The SEM observation therefore confirmed that the bonding between fibres and matrix was solid and could significantly increase the fracture toughness of the mix [40].

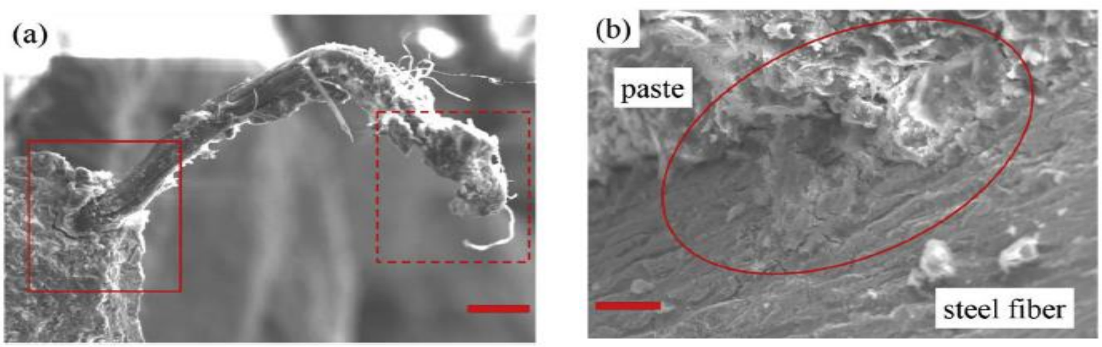


Figure 5. Microscale morphology of: (a): HE0.5 + PVA0.5 paste and (b): DHE0.5 + HE0.3 + PVA0.2 paste after 28-day curing. Scale bars are 20 µm. Red squares and circles indicate details of PVA fiber and steel fiber, respectively [40]

4 LESSONS LEARNED

Form the relevant literature review it is postulated that fibre reinforced composites enhance flexural performance, split tensile strength, toughness, ductility, microcracks resistance, corrosion resistance and reduces early age cracks. Bridging of the fibre in the matrix enhances strength and ductility. Pull out of fibre can be decrease by certain chemical treatment of fibre and surface treatment as it makes the surface rough due to removal of wax. Analyzed fibre matrix interface have elaborated different morphology of rough and serrated surface and its possible output in the fibrous composites. Continuous phase and a granular phase elaborated through BSE, verified the distribution of fibres in the fibrous matrix. Fibre continuity and fibre alignment can alter the performance in cracking pattern, more finding can conclude its effects. fibre volume fraction and resin volume fraction can be easily found through the study of high-resolution images and its outcome can be postulated with detailed studies of the matrix in different phases.

5 CONCLUSION

Following conclusions were made after extensive literature review:

- SEM analysis supported the investigations of effect of Distribution of fibres, its continuity and fibre alignment on mechanical properties.
- Surface treatment of the fibre make it rough and it can decrease the pull out of fibre from the matrix.
- SEM analysis can verify the bond between fibre surfaces and matrix and hence porosity and absorption of the fibre reinforced composites

ACKNOWLEDGMENT

The author would like to thank every person/department who helped thorough out the research work, particularly prof. Dr. Majid Ali for his kind and utmost sincere guidance in this study. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES:

[1] H. D. Wagner, H. E. Gallis, and E. Wiesel, "Study of the interface in Kevlar 49-epoxy composites by means of microbond and fragmentation tests: effects of materials and testing variables," J. Mater. Sci., vol. 28, no. 8, pp. 2238–2244, 1993.

[2] A. Shayan, I. Ivanusec, and R. Diggins, "Suitability of two rapid test methods for determining the alkali reactivity of sands," Cem. Concr. Compos., vol. 16, no. 3, pp. 177–188, 1994, doi: 10.1016/0958-9465(94)90015-9.

[3] A. Noumowe, "Mechanical properties and microstructure of high strength concrete containing polypropylene fibres exposed to temperatures up to 200 °c," Cem. Concr. Res., vol. 35, no. 11, pp. 2192–2198, 2005.

[4] D. Niu, L. Jiang, M. Bai, and Y. Miao, "Study of the performance of steel fiber reinforced concrete to water and salt freezing condition," Mater. Des., vol. 44, pp. 267–273, 2013, doi: 10.1016/j.matdes.2012.07.074.

[5] S. Pal, M. Shariq, H. Abbas, A. K. Pandit, and A. Masood, "Strength characteristics and microstructure of hooked-end steel fiber reinforced concrete containing fly ash, bottom ash and their combination," Constr. Build. Mater., vol. 247, p. 118530, 2020, doi: 10.1016/j.conbuildmat.2020.118530.

[6] V. Afroughsabet, G. Geng, A. Lin, L. Biolzi, C. P. Ostertag, and P. J. M. Monteiro, "The influence of expansive cement on the mechanical, physical, and microstructural properties of hybrid-fiber-reinforced concrete," Cem. Concr. Compos., vol. 96, no. June 2018, pp. 21–32, 2019, doi: 10.1016/j.cemconcomp.2018.11.012.

[7] L. Prabhu, V. Krishnaraj, S. Sathish, S. GokulKumar, and N. Karthi, "Study of mechanical and morphological properties of jute-tea leaf fiber reinforced hybrid composites: Effect of glass fiber hybridization," Mater. Today Proc., no. xxxx, 2019, doi: 10.1016/j.matpr.2019.09.132.

[8] J. S. S. Neto, R. A. A. Lima, D. K. K. Cavalcanti, J. P. B. Souza, R. A. A. Aguiar, and M. D. Banea, "Effect of chemical treatment on the thermal properties of hybrid natural fiber-reinforced composites," J. Appl. Polym. Sci., vol. 136, no. 10, pp. 1–13, 2019, doi: 10.1002/app.47154.

[9] A. Bentur and S. Diamond, "Crack patterns in steel fiber reinforced cement paste," Mater. Struct., vol. 18, no. 1, pp. 49–56, 1985, doi: 10.1007/BF02473364.

[10] R. MacVicar, L. M. Matuana, and J. J. Balatinecz, "Aging mechanisms in cellulose fiber reinforced cement composites," Cem. Concr. Compos., vol. 21, no. 3, pp. 189–196, 1999, doi: 10.1016/S0958-9465(98)00050-X.

[11] J. Rout, S. S. Tripathy, S. K. Nayak, M. Misra, and A. K. Mohanty, "Scanning electron microscopy study of chemically modified coir fibers," J. Appl. Polym. Sci., vol. 79, no. 7, pp. 1169–1177, 2001, doi: 10.1002/1097-4628(20010214)79:7<1169::AID-APP30>3.0.CO;2-Q.

[12] M. Safiuddin, M. Gonzalez, J. Cao, and S. L. Tighe, "State-of-the-art report on use of nano-materials in concrete," Int. J. Pavement Eng., vol. 15, no. 10, pp. 940–949, 2014, doi: 10.1080/10298436.2014.893327.

[13] A. Enfedaque, D. Cendón, F. Gálvez, and V. Sánchez-Gálvez, "Analysis of glass fiber reinforced cement (GRC) fracture surfaces," Constr. Build. Mater., vol. 24, no. 7, pp. 1302–1308, 2010, doi: 10.1016/j.conbuildmat.2009.12.005.

[14] E. A. Papon and A. Haque, "Fracture toughness of additively manufactured carbon fiber reinforced composites," Addit. Manuf., vol. 26, no. December 2018, pp. 41–52, 2019, doi: 10.1016/j.addma.2018.12.010.

[15] K. L. Scrivener, A. Bentur, P. L. Pratt, and E. M. Gartner, "Quantitative characterization of the transition zone in high strength concretes," Adv. Cem. Res., vol. 2, no. 6, pp. 79–81, 1989, doi: 10.1680/adcr.1989.2.6.79.

[16] A. Bentur and S. Diamond, "Fracture of glass fiber reinforced cement," Cem. Concr. Res., vol. 14, no. 1, pp. 31–42, 1984, doi: 10.1016/0008-8846(84)90077-2.
[17] Stella. L Marusin, "Sample Preparation - the Key to SEM Studies of Failed Concrete," Cem. Concr. Comps, vol. 17, pp. 311-318, 1995, doi.org/10.1016/0958-9465(95)00020-D.
[18] Z. Sun and Q. Xu, "Microscopic, physical and mechanical analysis of polypropylene fiber reinforced concrete," Mater. Sci. Eng. A, vol. 527, no. 1–2, pp. 198–204, 2009, doi: 10.1016/j.msea.2009.07.056.
[19] K. O. Kjellsen, R. J. Detwiler, and O. E. Gjørv, "Backscattered electron imaging of cement pastes hydrated at different temperatures," Cem. Concr. Res., vol. 20, no. 2, pp. 308–311, 1990, doi: 10.1016/0008-8846(90)90085-C.
[20] Y. Chen and Q. Wang, "Preparation, properties and characterizations of halogen-free nitrogen-phosphorous flame-retarded glass fiber reinforced polyamide 6 composite," Polym. Degrad. Stab., vol. 91, no. 9, pp. 2003–2013, 2006.
[21] H. Zhao and D. Darwin, "Quantitative backscattered electron analysis of cement paste," Cem. Concr. Res., vol. 22, no. 4, pp. 695–706, 1992, doi: 10.1016/0008-8846(92)90022-N.
[22] K. M. Nemati, "Fracture analysis of concrete using scanning electron microscopy," Scanning, vol. 19, no. 6, pp. 426–430, 1997, doi: 10.1002/sca.4950190605.
[23] C. M. Neubauer and H. M. Jennings, "The role of the environmental scanning electron microscope in the investigation of cement-based materials," Scanning, vol. 18, no. 7, pp. 515–521, 1996, doi: 10.1002/sca.1996.4950180708.
[24] F. Pelisser, O. R. K. Montedo, P. J. P. Gleize, and H. R. Roman, "Mechanical properties of recycled PET fibers in concrete," Mater. Res., vol. 15, no. 4, pp. 679–686, 2012, doi: 10.1590/S1516-14392012005000088.
[25] C. Redon and J. L. Chermant, "Damage mechanics applied to concrete reinforced with amorphous cast iron fibers, concrete subjected to compression," Cem. Concr. Compos., vol. 21, no. 3, pp. 197–204, 1999, doi: 10.1016/S0958-9465(98)00052
[26] M. G. Alexander, S. Mindess, S. Diamond, and L. Qu, "Properties of paste-rock interfaces and their influence on composite behaviour," Mater. Struct., vol. 28, no. 9, pp. 497–506, 1995, doi: 10.1007/BF02473154.
[27] M. R. Sanjay, P. Madhu, M. Jawaid, P. Senthamaraikannan, S. Senthil, and S. Pradeep, Characterization and properties of natural fiber polymer composites: A comprehensive review, vol. 172. Elsevier B.V., 2018.
[28] Q. Li, B. Huang, S. Xu, B. Zhou, and R. C. Yu, "Compressive fatigue damage and failure mechanism of fiber reinforced cementitious material with high ductility," Cem. Concr. Res., vol. 90, pp. 174–183, 2016.
[29] N. L. Lovata and M. F. Fahmy, "Interfacial bond study of a chemically treated polypropylene fibre-reinforced concrete," Constr. Build. Mater., vol. 1, no. 2, pp. 83–87, 1987, doi: 10.1016/0950-0618(87)90004-3.
[30] Y. L. Yue, G. Z. Li, X. S. Xu, and Z. J. Zhao, "Properties and microstructures of plant-fiber-reinforced cement-based composites," Cem. Concr. Res., vol. 30, no. 12, pp. 1983–1986, 2000, doi: 10.1016/S0008-8846(00)00376-8.
[31] Y. Geng and C. K. Y. Leung, "A microstructural study of fibre/mortar interfaces during fibre debonding and pull-out," J. Mater. Sci., vol. 31, no. 5, pp. 1285–1294, 1996, doi: 10.1007/BF00353108.
[32] L. Shang, G. Pan, N. Science, and T. D. Company, "Pergamon PI1 SOOOS-8846(97)00203-2," vol. 27, 1997.
[33] D. A. Silva, A. M. Betioli, P. J. P. Gleize, H. R. Roman, L. A. Gómez, and J. L. D. Ribeiro, "Degradation of recycled PET fibers in Portland cement-based materials," Cem. Concr. Res., vol. 35, no. 9, pp. 1741–1746, 2005.
[34] B. Felekoglu, K. Tosun, and B. Baradan, "A comparative study on the flexural performance of plasma treated polypropylene fiber reinforced cementitious composites," J. Mater. Process. Technol., vol. 209, no. 11, pp. 5133–5144, 2009.
[35] A. A. Ramezanianpour, M. Esmaeili, S. A. Ghahari, and M. H. Najafi, "Laboratory study on the effect of polypropylene fiber on durability, and physical and mechanical characteristic of concrete for application in sleepers," Constr. Build. Mater., vol. 44, pp. 411–418, 2013, doi: 10.1016/j.conbuildmat.2013.02.076.
[36] F. Elgabbas, E. A. Ahmed, and B. Benmokrane, "Physical and mechanical characteristics of new basalt-FRP bars for reinforcing concrete structures," Constr. Build. Mater., vol. 95, pp. 623–635, 2015.
[37] D. A. Hernandez, C. A. Soufen, and M. O. Orlandi, "Carbon fiber reinforced polymer and epoxy adhesive tensile test failure analysis using scanning electron microscopy," Mater. Res., vol. 20, no. 4, pp. 951–961, 2017.
[38] A. Zhou, R. Qin, C. L. Chow, and D. Lau, "Bond integrity of aramid, basalt and carbon fiber reinforced polymer bonded wood composites at elevated temperature," Compos. Struct., vol. 245, no. April, p. 112342, 2020.
[39] M. Usman Rashid, "Experimental investigation on durability characteristics of steel and polypropylene fiber reinforced concrete exposed to natural weathering action," Constr. Build. Mater., vol. 250, 2020.
[40] V. Afroughsabet, G. Geng, A. Lin, L. Biolzi, C. P. Ostertag, and P. J. M. Monteiro, "The influence of expansive cement on the mechanical, physical, and microstructural properties of hybrid-fiber-reinforced concrete," Cem. Concr. Compos., vol. 96, no. June 2018, pp. 21–32, 2019, doi: 10.1016/j.cemconcomp.2018.11.012.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

BOND OF NATURAL FIBERS WITH SURROUNDING CEMENTITIOUS MATRIX-A REVIEW

[a] Kaynat Arooj
a: Right Construction, Gujrat, Pakistan, kaynatarooj947@yahoo.com

Abstract-The need for sustainable material from renewable resources in the field of construction has become necessary due to large consumption of resources.Fibers obtained from plants are renewable.This literature study analyzes specifically; fiber used in various research, processing techniques, mechanical properties and their bonding mechanism in cement composites.Factors affecting the properties of concrete such as fiber types,fiber characteristics are also studied.It also presents the results obtained from pull-out tests conducted on embedded natural fibers in concrete mix.The purpose of this research is to investigate the effect of different treatment at the surfaces of natural fibers including their bonding in cement matrix. Four different treatments have been considered for this specific review. These treatment includes hybrid treatment using combination of horrification and polymer pigmentation, polymer pigmentation alone, horrification alone and alkali treatment using calcium hydroxide. A significant portion of this review is based on future trends related to the utilization of natural plant based fibers acting as curing agents and also as bond capacity improving material in cement composites.

Keywords- Bond strength, Natural fibers, Cementitious matrix.

1 INTRODUCTION

Construction industry is known as the most dynamic sectors throughout the world.Itcovers about 28% and 7% of employment both in skilled and unskilled areas, respectively. At the same time, construction sector is responsible for major depletion of large number of resources. The utilization of renewable resources in construction industry as a building material will facilitate to attain stable utilization pattern of resources. Concrete is the most used materialsin construction works because of its reliable compressive strength properties. Different fiber cement products are being produced which replaces mineral fiber by other fibers, i.e. PVA and polypropylene [1]. This shows a great change in field of construction to use plant based fiber cement material with properties same as synthetic fibers and are also cost effective as well as eco-friendly. Therefore, adding natural fibers in cement composites can be a better approach to attain sustainable construction. This study covers utilization of natural fibers in building material by reviewing past related publications.

Natural fibers consist of cellular structure. With various composition of cellulose, hemi-cellulosesas well as lignin comprise of various layers.Cellulose and hemi-celluloses are polymers made glucose units and various poly-saccharides, respectively. In case of lignin, it contains a mixture of heterogeneous and amorphous of aromatic polymers and also phenyl propane [2]. Fibers with difference in properties shows different behavior towards cement mix. Natural fibers show higher value of tensile strength and lower value of elasticity modulus; this shows a better performance when compared with synthetic fibers. One specific and significant draw backs of using natural fibers is their variation in properties due to which they show unpredictable variation in concrete properties [3, 4]. Performance of concrete can be enhanced by treating natural fibers using various methods and chemicals.

Cement composites along with aligned fibers shows tension-hardening behavior[5]. Researchers have used many models to predict the pull-out behavior of fiber based reinforced concrete. Naaman et al. proposed a method with bond–stress–slip relation of interface for fibers with smooth surfaces [6].

Naaman and Najm stated that fiber-matrix bond is influenced by four factors, (i) physical adhesion and chemical adhesion,(ii) mechanical component in bond, (iii) fiber interlocking, and (iv) friction [7]. Peled et al. studied that the friction stress for different matrices through pull-out behavior of natural fibers depending upon their mixture found to be 2.76MPA to 4.96MPA[8,9]. This can help to predict the bond shear stress versus slip curve, keeping in mind that method of back calculations can be applied in estimation of parameter by pull-out versus slip [10]. Naaman's presented a model of analyzing result of pull-out test, to verify bond properties in different fibers.

Therefore, due to demand of natural fibers for both structural and non-structural application in the field of civil engineering needs to be explored by latest use of technology like SEM,TGA. There is need to explore bond strength and pull out behaviour by the use of latest technology.

2 SURFACES OF NATURAL FIBERS

2.1 Surfaces of natural fibers for better bond.

The fiber amendment can be done based on three groups:1)physical treatments to improve their properties; 2) chemically treated fibers to increase interfacial bonding in fiber-matrix 3) both physical and chemical treatments of preserved good fibers.Physical treatments on the surfaces of natural fibers cause change in their properties and also in structure.This change in properties and structures of natural fibers (NF) effect their bond with composites. However, treating natural fibers with compatible chemicals leads to change in their properties and structure. Alkaline treatments affect fiber surface in two ways: 1) Increase in surface roughness, 2) Increase in number of cellulose exposed at fiber surface causing better interlocking between fiber cement matrixes. For composites with good physical as well as mechanical properties, increase in hydrophobic nature of natural fiber is the best solution ,which will improve the bond matrix.

2.2 Bond strength techniques.

Micro-mechanical testing (pull-out, micro-bond, disintegration, hornification) are of significant importancefor describing bond relation between fiber and matrix in cement composites.The processes that occur at the interface, one of the best techniques is the direct examination of interfacial failures through micro-mechanical failures. It helps to determine the time when cracks start occurring and also to check the already calculated values with actual process. Thus, interfacial de- bonding process can be differ from other processes. The method involving the direct observation of cracks beginning and spreading was developed and used in last few years, which caused significant improvement in data handling of micromechanical tests.

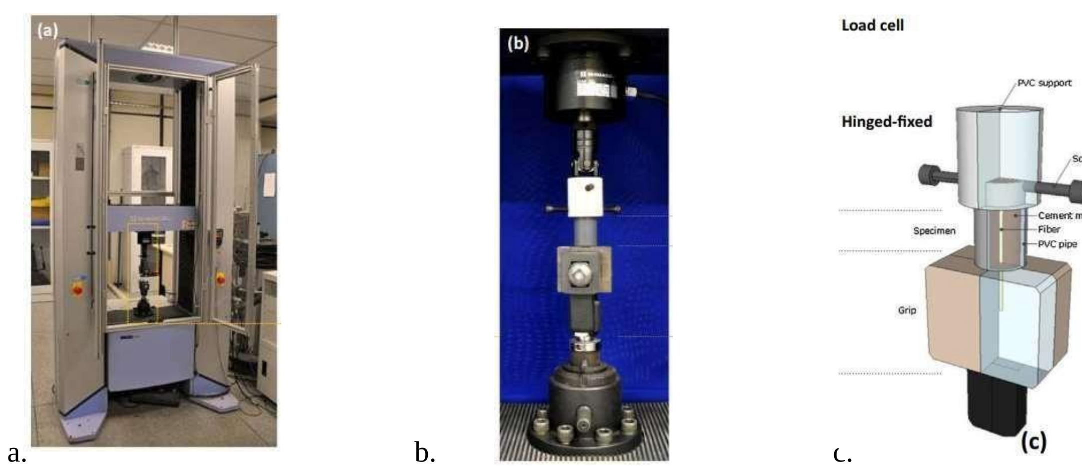


Figure 1: Pull-out testing setup: (a) Testing machine, (b) Pull-out testingsetup (c) detailed sketch of pull-out testing setup [11]

2.3 Bond strength investigation.

In spite of all advantages of natural fibers, there are also some draw backs of using them, which limited their application with cement composites in construction industry.The inter-facial bond among natural fibers and that of cement composites is comparatively weak [19].

2.4 Bond strength.

Natural fibers treated with different techniques and chemical leads to an improvement in their pull-out testing behavior. Fibers behave as bridge agent to create" bridging effect" in fiber matrix to enhance bonding strength between them. Adding natural fibers in concrete mix cause slip hardening during the process of pull-out testing. Fibers after horrification when treated with polymers, increase bond adhesion, that cause fiber fracture which is helpful for studying embedment lengths.

The difference in embedment length can lead to variation in pull-out mechanism. It can be noticed from the previously conducted studies that all treatments on NF results in improving their properties like, stiffness, adhesion and frictional bonding.

3 BONDING BEHAVIOR OF FRC AND ITS APPLICATIONS

Natural fibers obtained from raw materials of plants and vegetables are characterized by their compound micro-structure. But they offer great performance towards mechanical properties through tensile strength, which is commonly higher than the value of 200MPA [12-13]. Studies conducted on use of natural fibers shows their better properties and structure as compared to artificial and synthetic fibers. These studies describe that structure and properties of these fibers are somehow similar to those available in industry. While, to promote the use of natural fibers in construction industry as building material studies should be conducted on mechanism of bonding between natural fibers and cement composites.

The figure-2 shown below gives a detailed review of natural fiber. Micro-structure of a NF consists of many fiber cells, joined together with many small lamellas. These lamellas contain hemi-celluloses and ligninas well. Every single fiber-cell in natural fiber micro-structure consists of further four major parts, which is primary wall of fiber cell, secondary wall with certain thickness, tertiary wall of fiber cell and lumen. Natural fibers are different due to factor, like;number and area of lumens, quantity and size of these fiber-cells,walls of secondary cell with thickness and the cross-section, but they show same morphology.

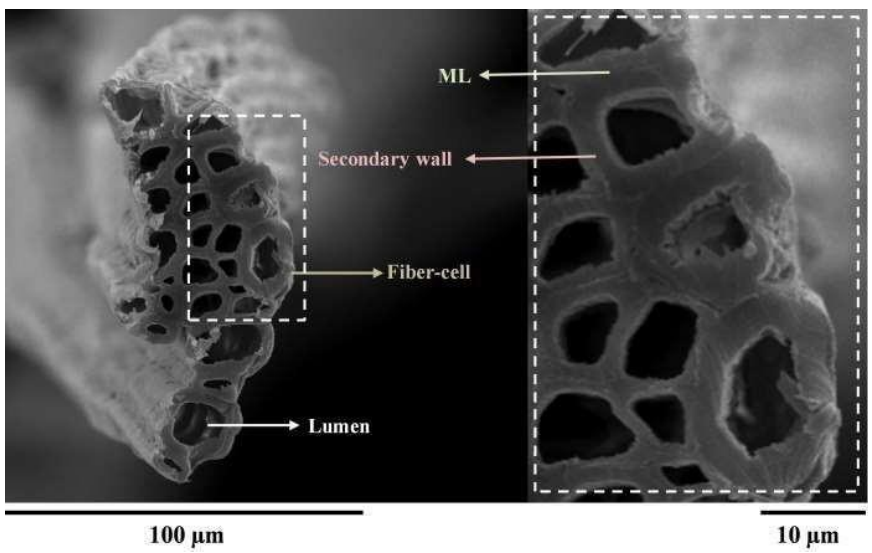


Figure 2: Microstructure of a natural fiber[14]

The factors such as lumen, fiber cells and secondary walls are reviewed for this specific study and few of these are presented(of specific fibers) in Table 1.. Example of fiber that consists of higher and lower lumen area are sisal, curaua and jute fiber. A single sisal fiber is made up of approximately 141 fiber cells with high lumen area value (about 5801 µm ^{2}). while, Curaua fiber contain high amount of fiber cells (about 305) and lowest lumen area (about 361 µm^2) with diameter of (about 0.81 µm).In case of jute fiber ,it is made of lowest quantity of fiber-cells (about 26), with lumen area of about 1000 µm^2[20, 22, 18]. It is a verification of the presence of hydrogen bridges hypothesis. Literature shows that the presence of hydroxyl group. in cellulose, hemi-celluloses and in lignin develop a great number of the hydrogen bonding among macro-molecules found inthe fiber cell of walls.

Breakage of hydrogen bonds takes place because of humidity, which are again developed by hydroxyl group when come in contact with water. This process of breaking down and again developing bond provoke swelling, as shown with a sketch in Fig. 3. Breaking down these bonds requires a high amount of energy. The number of cycles applied on fiber increase hydrogen bond, cause structural variation in walls of fiber and also increase the amount of AOH bonds. Increase in this specific group cause an increase in hydrophobicity of lignin. The carboxyl groupswhen connect with new hydrogen bonds comes up with an increase in lignin macromolecule network [16].

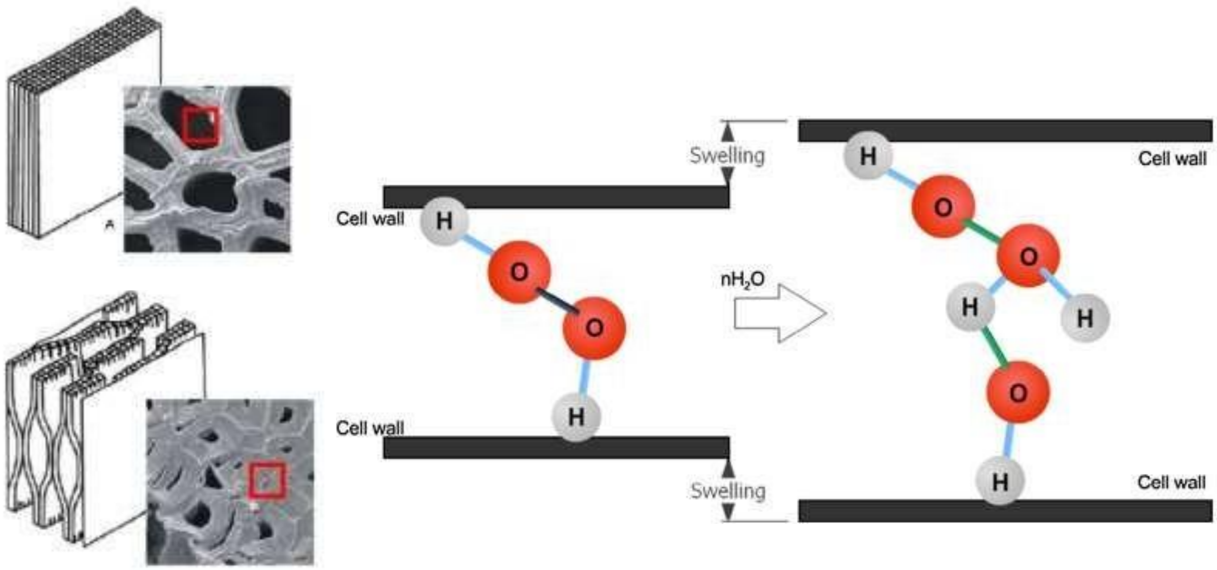


Figure 3: Schematic diagram showing swelling mechanism in wall of affecting bonding [15]

The process develops an improved bond among lignin, cellulose and hemicelluloses, giving stronger material, excellent stiffness and good strain capacity. Literature also shows that the presence of covalent bond between lignin and that of hemi-celluloses is same as present in inhabitant wood [17]. These lignins are covalently bound to hemicelluloses and these are bound to the cellulose with broad hydrogen nbonds.

Table 1: Nano-clay platelets with respective physical properties [21]

Color	Off-white
Density value(g/cm3)	1.99
d-Spacingvalue (001)(nm)	1.89
Aspect ratio value	220-1000
Surfacearea value(m2/g)	751
Size of Mean particle(lm)	6.1

Natural fiber starts absorbing a major amount of water after some specific time. Under normal conditions natural fibers have capacity to absorb approximately 200% of theirrespective weight [18].

The presence of hemi-celluloses,cellulose and lignin in plant fibers are responsible for absorbing high amount of moisture. Ligno celluloses fiber keeps on absorbing moisture until it gets saturated with water. This water covers the available spaces present between fibrils. Thus moisture absorption capacity is being reduced by various treatments. It can be noticed from literature that hornified technique cause reduction in moisture content by 15%, while, alkali treated, polymer treated and hybrid treated fibers reduce moisture content by 17.5%, 25% and 50%, accordingly.

Decrease in capacity of water absorption can be related with minor losses of hemi-celluloses and that of lignin, shown as TG analysis and the changes occur between chemical bonds making fibers further hydrophilic. In hornified treatment of fiber, moisture absorption capacity decreases after many cycles of wetting and drying . This process of wetting and drying increase the packing of fiber cells, while decreasing lumen. This result in minimizing moisture absorption capacity of fibers. For alkali treatment method, the mechanism is related to the removal of the lignin and that of hemi- celluloses, because of which it absorbs high quantity of water. Using polymer promotes for a coating layer, which specifically decreases its capacity to absorb water. In combination with hornification technique, it seems to be an effective method for high hydro-phobicity performance. It is believed that polymers penetrate in fiber cells ,this reduce the moisture absorption capacity of fibers.

4 DISCUSSION

The use of natural fibers as building material in cement matrix has gained so much importance because of its ability to enhance weaknesses in mortars. Fibers present in concrete mix develop bridging effect along the cracks, which reduce cracking propagation. Therefore, natural fiber reinforced cement concrete (NFRCC) are referred because of their high tensile, flexural strength also due their ductile behavior and ductility resulted from cracks reduction. The factors controlling the post-cracking behavior in fiber reinforced cement concrete(FRCC)may effect the design criteria for FRCC members. The factors that control the post cracking behavior includes; fiber proportion, fiber structure, their distribution and position in cement matrix, their properties and their chemical bond with matrix.

Micro-mechanical single fiber test can provide significant information related to strength of inter-facial bonding through the direct observation of cracks at their intiation and propagation. The inter-facial factors such as, interfacial shear strength (IFSS) and that of critical energy provide more reliable data than other conventional values. The values thus calculated had three independent micro-mechanical methods. The applied load to observe the distribution of shear stress experimentally along the interface of the produced cracks length shows the single shear lag produced due to applied load being function of internal failure. The stress and energy-based local failure criteria in similar way characterize the variations of interfacial bond quality upon fiber sizing for all systems investigated. By varying the size of natural fibers changes in IFSS are observed rather than aramid fibers because of various internal failure modes. The strength of natural fibers and those macro composites with sized as well as un-sized natural fibers correlates very well with bond strength investingated with the help of micro-mechanical testing such as pull-out testing etc. shown Figure3 below.

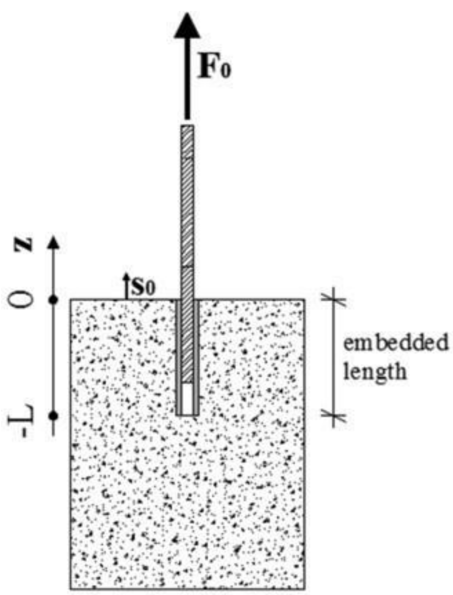


Figure 3: Schematic diagram showing pull-out behavior [23]

By increasing surface roughness, significant amendments can be done by above mention treatment as it results in disruption of hydrogen bonds in present network structure. It may develop a broad network of hydroxyl bond because of change in molecular hydrogen bonding.

5 CONCLUSION

Present research work presents all researches'conducted in recent past years regarding use of natural fibers in cement-based composites, depending upon their preparation techniques, properties, their methods to improve bonding between fiber-matrix and proportions. Keeping in mind all the facts, following conclusions can be made:

- Increase in embedment length cause an increase in pull-out force, however, no progress occurs in shear strength of bond after increase in embedded length from 10mm-40mm.
- The hornification method of treatment seems to be the simplest solution to enhance mechanical properties as well as bond to cement system. These properties can also be improved during the process of wetting and drying.

- Properties of NF depend on their origin, structures,their age and also on their experimental condition (i.e. diameter of fiber, length of gauge, temperature). These properties can be improved by removal of impurities present on the surface of natural fibers which reduce water absorption and enhance properties related to fiber- matrix.
- Removing impurities from the surface of the NF can facilitate the mechanical inter-locking also bond reaction that occur because of hydroxyl group's disclosure in chemicals for example resins and dyes.
- The bond between fiber composites and that of concrete mix can be strengthened by adding a calculated proportion of fine sand into water epoxy coating.
- In case of polymer treatment, high fiber-matrix bond can be achieved with better frictional mechanism and slip hardening.
- Boiled fibers with thickness ranging from 0.30-0.35mm show more tensile strength than those with thin surfaces dried and treated with chemicals.
- Change in embedment length can affect the bond strength of fiber and matrix. It has the highest embedded length value of 30mm.

The results obtained from conducted research will pave path for detailed study and understanding of mechanical behavior of natural fibers in cement matrix. Above all, the study will look for structural application of NFRC members through their mode of response.

ACKNOWLEDGMENT

The author would like to thank Prof. Dr. Majid Ali for his kind and valuable guidance throughout this research work. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCESS

[1] Ali, M., Li, X., & Chouw, N. (2013). Experimental investigations on bond strength between coconut fibre and concrete. Materials & Design, 44,596-605.

[2] Beckermann, G. W., & Pickering, K. L. (2008). Engineering and evaluation of hemp fibre reinforced polypropylene composites: fibre treatment and matrix modification. Composites Part A: Applied Science and Manufacturing, 39(6),979-988.

[3] Diaz, J. P. V., de Andrade Silva, F., & d'Almeida, J. R. M. (2016). Effect of peach palm fiber microstructure on its tensile behavior. BioResources, 11(4), 10140-10157

[4] Li, Z., Wang, X., & Wang, L. (2006). Properties of hemp fibre reinforced concrete composites. Composites part A: applied science and manufacturing, 37(3),497-505.

[5] Pacheco-Torgal, F., & Jalali, S. (2011). Cementitious building materials reinforced with vegetable fibres: A review. Construction and Building Materials, 25(2),575-581.

[6] Zhou,Y.,Fan,M.,&Chen,L.(2016).Interfaceandbondingmechanismsofplantfibrecomposites:Anoverview. Composites Part B: Engineering, 101,31-45.

[7] Ferreira,S.R.,Martinelli,E.,Pepe,M.,deAndradeSilva,F.,&ToledoFilho,R.D.(2016).Inverseidentification of the bond behavior for jute fibers in cementitious matrix. Composites Part B: Engineering, 95,440-452.

[8] Ferreira, S.R., deAndradeSilva,F., Lima,P.R. L.,&Toledo Filho, R.D.(2017).Effect of hornification on the structure, tensile behavior and fiber matrix bond of sisal, jute and curauá fiber cement based composite systems. Construction and Building Materials, 139,551-561.

[9] morphology on interfacial bond and cracking behaviors of sisal fiber cement based composites. Cement and Concrete Composites, 33(8), 814-823.

[10] Hakamy, A., Shaikh, F. U. A., & Low, I. M. (2013). Microstructures and mechanical properties of hemp fabric reinforced organoclay–cement nanocomposites. Construction and Building Materials, 49, 298-307..

[11] Ferreira, S. R., Pepe, M., Martinelli, E., de Andrade Silva, F., & Toledo Filho, R. D. (2018). Influence of natural fibers characteristics on the interface mechanics with cement based matrices. Composites Part B: Engineering, 140, 183-196.

[12] Walton, P. L., & Majumdar, A. J. (1975). Cement-based composites with mixtures of different types of fibres. Composites, 6(5),209-216.

[13] Banthia, N., & Sheng, J. (1996). Fracture toughness of micro-fiber reinforced cement composites. Cement and Concrete Composites, 18(4),251-269.

[14] Delvasto, S., Toro, E. F., Perdomo, F., & de Gutiérrez, R. M. (2010). An appropriate vacuum technology for manufactureofcorrugatedfiquefiberreinforcedcementitioussheets.ConstructionandBuildingMaterials,24(2), 187- 192.

[15] Ferreira, S. R., de Andrade Silva, F., Lima, P. R. L., & Toledo Filho, R. D. (2015). Effect of fiber treatments on the sisal fiber properties and fiber–matrix bond in cement based systems. Construction and Building Materials, 101, 730-740.

[16] Brandt,A.M.(1987).Present trends in the mechanics of cement based fibre reinforced composites.Construction and Building Materials, 1(1),28-39.

[17] Mansur, M. A., & Aziz, M. A. (1982). A study of jute fibre reinforced cement composites. International Journal of Cement Composites and Lightweight Concrete, 4(2),75-82

[18] Ferreira, S. R., Martinelli, E., Pepe, M., de Andrade Silva, F., & Toledo Filho, R. D. (2016). Inverse identification of the bond behavior for jute fibers in cementitious matrix. Composites Part B: Engineering, 95, 440-452.

[19] Snoeck, D., & De Belie, N. (2012). Mechanical and self-healing properties of cementitious composites reinforced with flax and cottonised flax, and compared with polyvinyl alcohol fibres. Biosystems Engineering, 111(4), 325-335.

[20] Zollo, R. F. (1997). Fiber-rein Snoeck, D., & De Belie, N. (2012). Mechanical and self-healing properties of cementitious composites reinforced with flax and cottonised flax, and compared with polyvinyl alcohol fibres. Biosystems Engineering, 111(4), 325-335.orced concrete: an overview after 30 years of development. Cement and concrete composites, 19(2),107-122.

[21] Alhuthali, A., Low, I. M., & Dong, C. (2012). Characterisation of the water absorption, mechanical and thermal properties of recycled cellulose fibre reinforced vinyl-ester eco-nanocomposites. Composites Part B: Engineering, 43(7), 2772-2781.

[22] Coutts,R.S.P.,&Warden,P.G.(1990).Effect of compaction on the properties of air-cured wood fibre reinforced cement. Cement and concrete composites, 12(3), 151-156.

[23] J.T. Kim, A.N. Netravali, Mercerization of sisal fibers: effect of tension onmechanical properties of sisal fiber and fiber-reinforced composites, Compos.A Appl. Sci. Manuf. 41 (2010) 1245–1252.

[24] Pacheco-Torgal, F., & Jalali, S. (2011). Cementitious building materials reinforced with vegetable fibres: A review. Construction and Building Materials, 25(2),575-581.

[25] [Ardanuy,M.,Claramunt,J.,&ToledoFilho,R.D.(2015).Cellulosic fiber reinforced cement-based composites: A review of recent research. Construction and building materials, 79,115-128.

[26] Javadian, A., Wielopolski, M., Smith, I. F., & Hebel, D. E. (2016). Bond-behavior study of newly developed bamboo-composite reinforcement in concrete. Construction and Building Materials, 122,110-117.

[27] Lau, K. T., Hung, P. Y., Zhu, M. H., & Hui, D. (2018). Properties of natural fibre composites for structural engineering applications. Composites Part B: Engineering, 136,222-233.

[28] Ferreira,S.R.,Martinelli,E.,Pepe,M.,deAndradeSilva,F.,&ToledoFilho,R.D.(2016).Inverse identification of the bond behavior for jute fibers in cementitious matrix. Composites Part B: Engineering, 95,440-452.

EFFICIENCY OF XRD METHOD FOR STUDYING FRC COMPOSITES –A REVIEW

[a] Haroon Imtiaz, [b] Talha Ahmed
a: Faryal Builders and Contractors, Islamabad, haroon.imtaiz98@.gmailcom
b: Department of Civil Engineering, Capital University of Science and Technology, engr.talhaahmed@outlook.com

Abstract- The appropriate and proficient management of different types of fibrous materials is one of the major concerns by the agricultural countries. The plenty of natural as well as synthetic fibres from the last few decades are used by researchers for different civil engineering applications. The properties of fibres differ from each other depending upon their growing condition, harvesting and extraction method. The different fibre reinforced concrete are similar as of their texture apparently but differs structurally. Microscopic examination plays a vital role in identification of mineral composition. The microscopic study to explore micro-structure of fibre reinforced composites (FRC) needs to be done. A variety of methods are available for studying the material characterization at micro-level. This paper preliminary focuses on the characterization and efficiency of fibre reinforced composites through X-ray diffraction (XRD) test. XRD test is widely used to determine the cellulose and lignin composition. XRD test is most suitable for identification of crystallographic structure providing the crystallinity index as well. Similarly, Composition of lignin, cellulose and can be detected by use of XRD analysis. The detailed discussion on structural characterization is made.

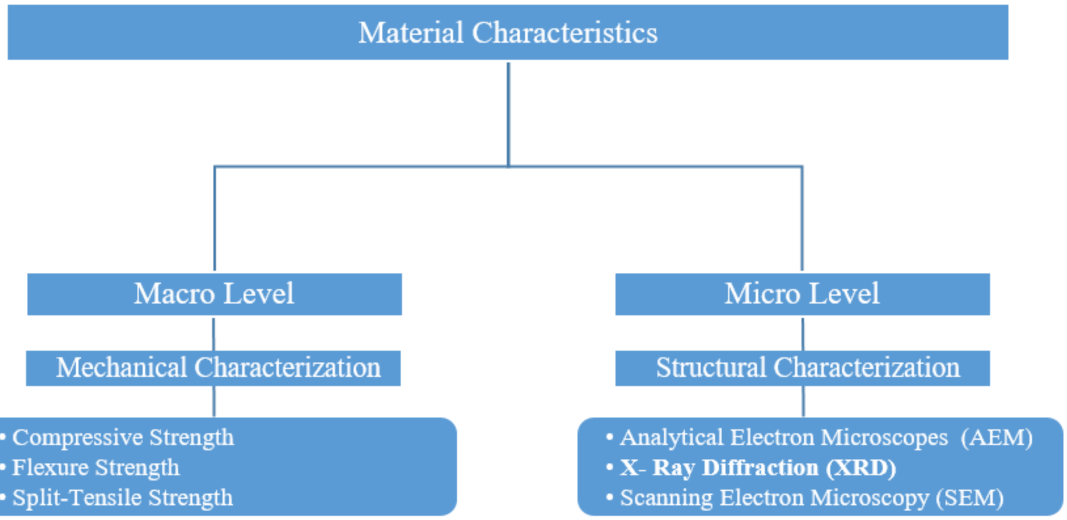
Keywords- X-ray diffraction, Fibre Reinforced Concrete, Material Characterization.

1 INTRODUCTION

The innovation of X-rays in 1895 by Wilhelm Conrad permitted the new applications possible in all major disciplines of engineering as well as scientific making the use of X-rays more beneficial. (Roentgen, 1895) [1]. The objective of this work focuses on the efficiency of XRD test for analyzing the material characterization at micro-level as shown in Figure 1. In particular, Laue, Knipping and Friedrich initiated the study of crystals by X-rays and opened new possibilities to study the crystalline materials by using the X-ray diffraction to explore material characterization (Friedrich et al., 1913) [2]. The advancement in technological phase promoted use of X-rays like X-ray radiography, X-ray computer tomography, X-ray fluorescence spectroscopy etc. [4] The advance technologies are used for different composites study. The application of XRD method on crystals is a precise study of crystalline phase structure in a characteristic manner by the ability of crystals to diffract X-rays [5].

To date, having environment friendly materials is one of the current trends in the construction industry with the help of effectively utilization of natural fibres as an alternative of man-made or synthetic fibres in concrete [6-8]. Fiber reinforced concrete (FRC) for the use of structural applications has proven itself to be a comparable material due to its improved mechanical properties [9-11]. The use of fibres are seeking attention because of their light weight and improved mechanical properties [26]. Different industries like ceramic, polymer and construction industry have several applications of nanotechnology producing composites which are more improved and comparable mechanical and physical properties. [12]. The improvement of cementitious matrices and polymers for improving their fracture resistance and strength properties is greatly influenced by the use of cellulose and natural fibres [13,14]. Natural fibres are biodegradable, lighter and cheaper, than its equivalent man-made fibres. Wheat straw, cotton, rice straw, sisal, bagasse, flax, bamboo, hemp, banana, coir, and others are some of the examples of natural fibres [15-17]. Indeed, some obstacles which have limited the applications of fibres in the composites despite of all their advantages of fabrics and natural fibres. The FRC composites look apparently same because of presence of fibres but actually they differ structurally. Hence, having the different bond behaviour and different mechanical characteristics. The material characterization of natural fibres like jute, kenaf, hemp, coir, sisal and flax and their composites are explored by significant amount of research works and can be find on. The natural fibres particularly are in raw form having impurities in it. The fibres can be amended and make more effectively incorporated. Physical and chemical methods are most adopted methods by which the surface of natural fibres can be modified which can make significant improvement in material characteristics.

Figure 1: Material Characterization Techniques



In engineering and material science field, the application of XRD method on crystals is a precise study of crystalline phase structure in a characteristic manner by the diffraction of X-rays and by the ability of crystals. The patterns recorded by diffraction analysis of the sample contains the influence of numerous micro- and macro structural features. With the, space group, macro stresses, peak position and lattice parameters the qualitative phase analysis or chemical composition can be examined. The information about the structure of crystals including occupancy, atomic position and temperature as well as quantitative phase including the texture can be obtained by the peak intensity. Therefore, the peak shape gives the detailed information about the sample micro-strains and crystallite sizes (Dinnebier and Billinge, 2008) [5]. In this study, the method of XRD and its material characterization with different composition level of crystalline and amorphous state of FRCs are discussed. The evaluation of XRD is emphasized on FRC in order to better understand the structural characterization in FRCs. The determination of crystallinity index of FRCs is also explained.

2 Overview of XRD Methodology

2.1 *Sample preparation.*

One of the most important requirements for XRD analysis is proper sample preparation. Sample preparation includes not only to remove undesirable substances by the precise sample treatments, but also appropriate and efficient techniques to get desirable thickness, orientation and particle size etc. To achieve good signal without distortion and fluctuation extremely fine grained sample are required for the analysis of XRD, and minimize preferred orientation to avoid spottiness. As reported by Brindley, 1980 and Cullity, 1978) [17], The recommended range of size for sample is around 1 µm to 5µm The mesh size of sieve 325 (45µm) is usually used for the sample sieving for the use qualitative evaluation of mineral components.

2.2 *Technology involved in XRD laboratory equipments.*

Generally, in labs stationary equipment is used. The main parts of the instruments for XRD are a sample holder, goniometer, primary and secondary optics with and an X-ray source having a detector as shown in Figure 2. Goniometer is essential part of the equipment and all XRD equipments are equipped with a goniometer, The X-ray source are allowed to move through the goniometer which is the dominant part of the diffractometer, similarly in a very precise manner the detector and sample are placed relative to each other. While, the generation and acceleration of electrons is necessary for the generation of X-ray photons coming which can be done by the use tungsten filament. Generally, for the acceleration of electrons the voltage range between 20 to 60 kV are used (Spieß et al., 2009) [4]. For the production of X-rays 99% of the energy is dissipated in the form of heat and only 1% of the available energy is used for the generation of the radiation.

Moreover, the consideration of heating is a major issue which affecting the efficiency of the X-rays. Therefore, it is mandatory to cool down the system and instrument by using anode having continuous water cooling. While, limiting the beam intensity to 60mA and low current can be used in X-ray tubes.

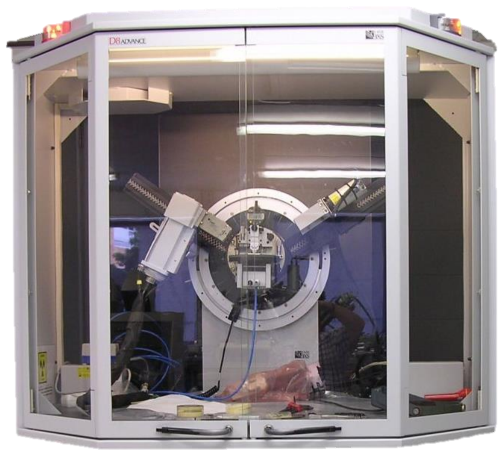


Figure 2: XRD equipment (D8 Bruker-AXS Advance Diffractometer [18]

2.3 *Employment Technique.*

Goniometer being the crucial part of the diffractometer which allows the movement of X-rays hereby all laboratory equipments of XRD are equipped with it. According to the purpose and required need of the measurement, particular sample holders e.g., automatic sample changing, continuous translation or sample rotation to achieve automatic sample positioning, etc., or considering the sample geometry a controlled preparation environment can be used. The use of glass plated can be done for powdered samples of amorphous polymer for carrying the powder. The additional rotation axes are generally required for the texture and residual stresses measurements, in addition to position these investigations of the sample are needed for these investigations.

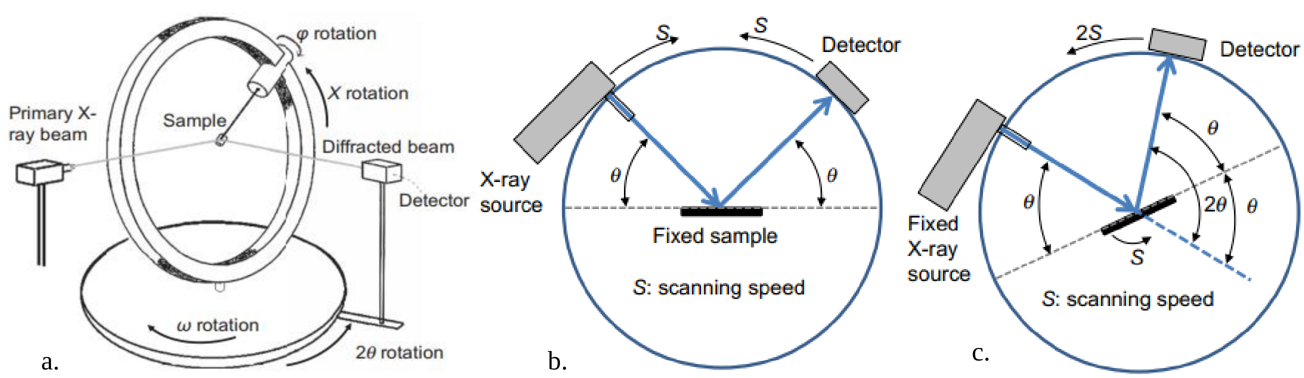


Figure 3: Employment Technique, a. principle of goniometer, b. ϴ/ ϴ goniometers, c. ϴ/ 2ϴ goniometers [18]

The basic method of employment is shown in Figure 3. where the sample is fixed while, the detector as well as X-ray source moves, and at a fixed position Similarly, for the next round sample and detectors are moving with goniometer and the X-ray source is fixed. Both the actions can be done simultaneously depending upon the ability of detectors to read.

2.4 *Employment Technique.*

According to the peak height from the X-ray diffractogram, the Crystalline Index (CI) or degree of Crystallinity in cellulosic material technique can be determined by the established Segal empirical equation (Segal et al. 1959) [19], as shown in equation 1.

$$C.I = \frac{I200-IAM}{I200} \qquad (1)$$

Where: I_{200} is the maximum intensity of reflection by the crystalline plane of the cellulose at 2Θ and I_{am} is the maximum intensity of the amorphous part at 2Θ.

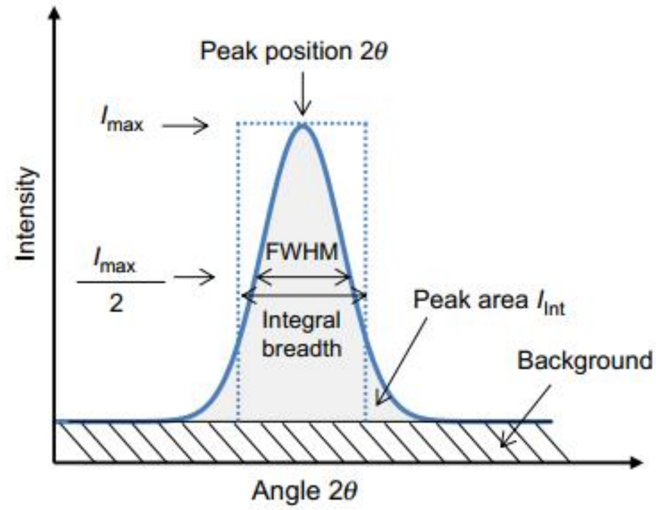


Figure 4: Information about diffraction peak [18]

In general, as a function of angle 2Θ the intensity distribution is extracted from the diffraction data. The information that can be extracted from the diffraction peaks is represented in Figure 4.

3 REVEALED CHARACTERISTICS OF FRC THROUGH XRD

2Θ The mineral constituents as well as the textures (i.e. size, shape and arrangement of mineral constituents within the groundmass for both concretes are largely similar. However, microstructurally they are quite distinct. Many research by various researchers to study the change in the microstructure and surface morphology after the treatment of fibres are studied. The interfacial bonding can be improved by removing the cementing substances and impurities which can increase the effective area providing better interlocking and improved properties. [20-21]. Punyamurthy et al.[22] reported that the by the treatment of fibres the surface roughness can be increased this is because of the removal of hemicellulose and lignin removal . Symington et al. reported that excessive treatment of fibre can lead towards fibre cracking phenomena and can have adverse effect on mechanical properties of natural fibres. The examples of over treated fibres are kenaf, abaca, flax and sisal fibres

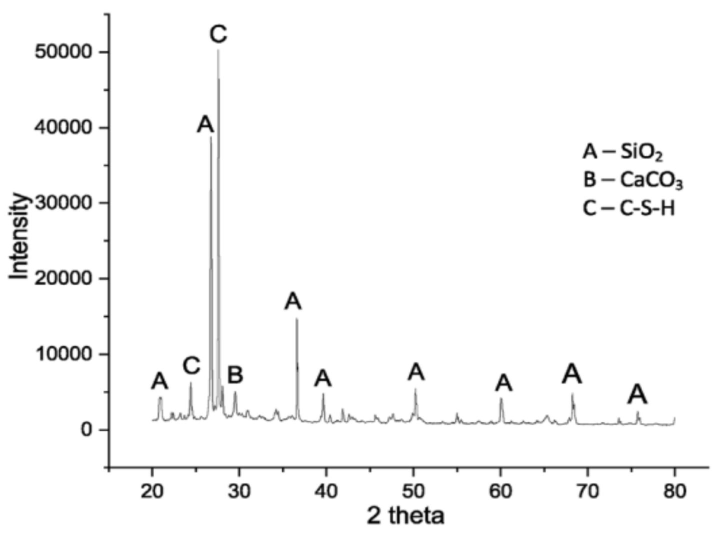


Figure 5: XRD pattern of Bagasse Fibre Composite [25]

Fiore et al. subjected to the treatment of kenaf fibres improve surface morphology, which leads to increase the mechanical properties by the removal of surface impurities and other cementitious impurities, this was done by alkaline treatment of 48 hours [23].

The XRD analysis of the composites after the curing time of 28 days in water is shown in Fig. 5. Most commonly produced X-ray patterns are of crystalline materials like cristobalite and quartz. In the diffraction analysis both O and Si have long-range atomic number and are arranged differently this arrangement of O and Si are reflected in the diffraction analysis. The O and Si atoms are organized differently, but both have atomic order of long range and the difference of their crystals structure are is reflected in the observed diffraction peaks. The broad scattered pattern of XRD analysis if observed by the amorphous glass because it does not have long-range atomic order. Fig. 6 shows the Quartz (SiO2) effect in the diffraction peaks. There is small presence and effect of hydrated compounds such as $Ca(OH)_2$, C–S–H, and $CaCO_3$. The content present of SiO2 in the mixture can increased due to the presence of micro-silica affecting its content ratio. Similarly, in the presence of water, reaction of silica ($SiO_{2)}$ with calcium hydroxide ($Ca(OH)_{2)}$ leads to the formation of C–S–H gel in the concrete mix. The peak of $Ca(OH)_2$ in the diffraction can be disappeared. The formation of C–S–H gel can turn to increase the strength of composites because the amount of SiO_2 decreases and more silica is used to react with Ca(OH)2 in the presence of water. Thus, calcite being the filler material in form of calcium carbonate contributes to enhance the strength of composites. This implies the formation of C–S–H gel comes in hydration reaction in which silica plays and important role. The presence of by-products such as calcium carbonate and calcium hydroxide are present but are in less ratio.

One of the challenging part is the phase identification of nanoscale material by XRD because of nearly indistinguishable patterns obtained by the diffraction analysis. For example, Ag and Au have similar structure lattice and both are face-centered cubic metals, which have broadened and scattered peaks obtained by XRD and is a tedious job which cannot be differentiated by XRD. Similarly, the XRD patterns of magnetite Fe_2O_3 and magnetite Fe_3O_4 two forms of iron oxide, are sufficiently similar with broad peaks, and they cannot be distinguished by XRD patterns. Differentiating the nitrides Ni_3N and nickel carbides Ni_3C or any hexagonal close-packed form can be similarly challenging. In these particular and other similar cases, the phase identification for additional characterization techniques are important [24].

4 RESEARCH FINDINGS/ FINDINGS DRAWN/ LESSON LEARNED

Material characterization under the influence of various condition like treatment methods, absorption of water and loading methods etc.is an important aspect for the natural fibres and its composites to understand their behaviour. A visual or manual control and selection of peak needs to be done once the preselection of possible phases are defined for the selected pattern. The intensity variation from the ideal peak and due to the solid part or strain needs to be taken in part. The macroscopic strains as well as texture effects can be avoided for the case of fine powder samples, and therefore measurements and can actually match up to some extent with the theoretical patterns precisely. In contrast to all of these,

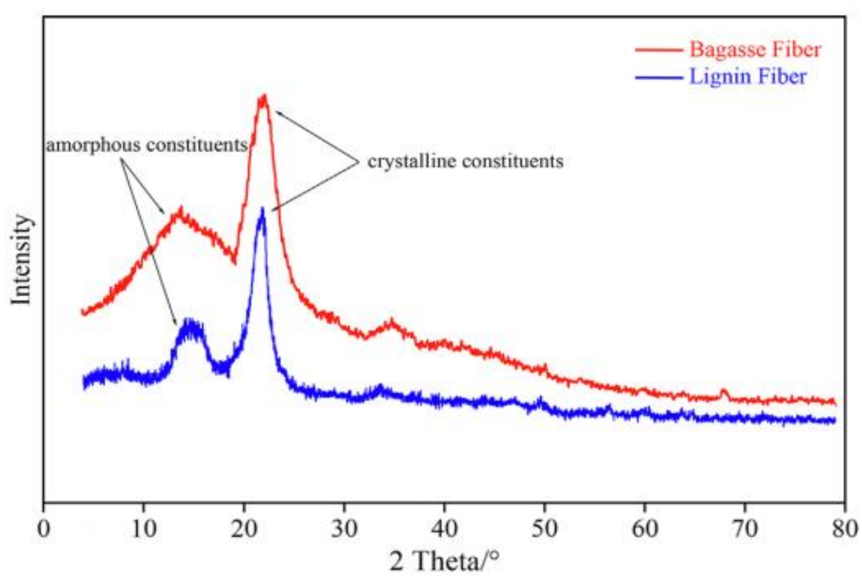


Figure 6: XRD pattern of Bagasse Fibre Composite [24]

the engineering mechanisms and samples which are more solid can reveal the textures more strongly, large grains and therefore the poor diffraction and irregular peak shape or due to high conditions of microscope the peaks shift or scatter. The adoption of the present final phase selection by the user to be performed only, based on the required results and of this understanding about measurement conditions and measurement conditions of the investigated sample. For an ideal case of diffraction, all the peaks measured of diffraction obtained from XRD should be assigned to a phase.

Crystallographic structure of sisal fibres was analyzed by Sahu [27] and reported that fibers mainly contain lignin, hemicellulose and cellulose. Cellulose is mainly composed of crystalline and that of amorphous structures, whereas the hemicellulose and lignin shows amorphous behavior. Development of the new hydrogen bonds among cellulose enhance crystalline percentage and crystallinity index of the natural fibers by treatment of fibres. The lignin part has amorphous structure and cellulose are crystalline in nature. The elimination of non-cellulosic parts makes fibre more crystalline and this is learned from XRD pattern.

Table 1: .Variation of crystalline index and crystalline percentage of treated and untreated fibre composite

Fibre Studied	Maximum Intensity	Angle (2-Theta) at I_{200}	Maximum Intensity	Angle 2 Theta at Iam	Crystallinity Index	Percentage of Crystallinity
	I_{200}	$2\ \Theta - I_{200}$	I_{am}	$2\Theta - I_{am}$	CI	%
Sisal	4085	22.42	2246	15.98	0.45	64.52
Treated Sisal	5814	22.38	2688	16.22	0.53	68.30

Based on the prominent analysis of the FRCs, by the XRD pattern the source of the peaks can be confirmed. The observed peaks are represented in Fig. 6. The XRD pattern of the fibre reinforced composites show a peak at 2Θ, which represents the cellulose in form of crystalline constituents, the peak of amorphous denotes constituents like amorphous, lignin, and hemicelluloses. The treatment of natural fibres irrespective of any method the crystallinity index also tends to increase with their treatment. Most of this carbonation has taken place at the interface of the aggregates and few of them are associated with micro cracks and voids. On the basis of present investigation, it is concluded that the use of calcium stearate as admixture can enhance the strength and durability properties of concrete due to batter microstructure, formation of additional C-S-H gels and infilling of pores. Therefore, peak intensity tends to increase with the pretreatment of natural fibres and this pretreat of fibres can be done by various techniques such as chemical, alkaline treatments etc.

5 CONCLUSION

Since from the first experiment of XRD and the innovation of X-rays used for the crystals, among one of the most prevailing technique of art to explore material characterization is by mean of XRD methods. The design of high performance materials and their components have been strongly improved by the improved knowledge about properties of components, crystal structure and microstructure. Based on the review of XRD for FRC composites following conclusions are drawn

- The sample preparation requires to be extremely fine grained to achieve good signal without distortion and fluctuation extremely fine grained sample are required for the analysis of XRD, and minimize preferred orientation to avoid spottiness. The recommended range of size for sample is around 1 µm to 5µm.
- The interfacial bonding can be improved by removing the cementing substances and impurities which can increase the effective area providing better interlocking and improved properties
- The crystallinity index may vary because of the present impurities and can be removed by treatment of fibres.
- XRD is recommended to observe crystals behaviour, but for detailed investigations digital image processing techniques can be applied because of their advance revealing properties.

On the other side, In the present era present studies and new developments still ongoing, especially for the exploration of geometries, bonding of materials, complex material investigations and their applications. The advancements in the field of the high resolution XRD and energy-dispersive methods are opening new possibilities of investigations.

ACKNOWLEDGMENT

The author would like to give special thanks to Prof. Dr. Majid Ali for his kind support and acknowledge the organization and persons, especially who helped throughout this study. The careful review by the anonymous reviewers are also gratefully acknowledged.

REFERENCES

[1] Röntgen, W. C. (1895). Uber eine neue Art von Strahlen. Sitzungsber Phys Med Ges Wurtzburg, 9, 132-141.
[2] Friedrich, W., Knipping, P., & Laue, M. (1913). Interferenzerscheinungen bei roentgenstrahlen. Annalen der Physik, 346(10), 971-988.
[3] Cui, J. H., Xie, Z. Q., & Xiao, H. J. (2013). Cause Analysis on the Cracks in Concrete Plate of Canal Lining. In *Applied Mechanics and Materials (Vol. 405, pp. 2596-2599)*. Trans Tech Publications Ltd.
[4] Spieb, L., Teichert, G., Schwarzer, R., Behnken, H., Genzel, C., 2009. Moderne R€ ontgenbeugung, second ed. Teubner Verlag, Wiesbaden.
[5] Dinnebier, R. E., & Billinge, S. J. (2008). Principles of powder diffraction. Powder Diffraction: Theory and Practice, 1-19.
[6] Low, I. M., Somers, J., Kho, H. S., Davies, I. J., & Latella, B. A. (2009). Fabrication and properties of recycled cellulose fibre-reinforced epoxy composites. *Composite Interfaces*, 16(7-9), 659-669.
[7] Ahmed, S. F. U., Maalej, M., & Paramasivam, P. (2007). Flexural responses of hybrid steel–polyethylene fiber reinforced cement composites containing high volume fly ash. *Construction and building materials,* 21(5), 1088-1097.
[8] Jarabo, R., Fuente, E., Monte, M. C., Savastano Jr, H., Mutjé, P., & Negro, C. (2012). Use of cellulose fibers from hemp core in fiber-cement production. Effect on flocculation, retention, drainage and product properties. *Industrial Crops and Products*, 39, 89-96.
[9] Di Prisco, M., Plizzari, G., & Vandewalle, L. (2009). Fibre reinforced concrete: new design perspectives. *Materials and structures*, 42(9), 1261-1281.
[10] De la Fuente, A., Aguado, A., Molins, C., & Armengou, J. (2011). Innovations on components and testing for precast panels to be used in reinforced earth retaining walls. *Construction and Building Materials*, 25(5), 2198-2205.
[11] Alhuthali, A., Low, I. M., & Dong, C. (2012). Characterisation of the water absorption, mechanical and thermal properties of recycled cellulose fibre reinforced vinyl-ester eco-nanocomposites. *Composites Part B: Engineering*, 43(7), 2772-2781.
[12] de Andrade Silva, F., Mobasher, B., & Toledo Filho, R. D. (2009). Cracking mechanisms in durable sisal fiber reinforced cement composites. *Cement and Concrete Composites*, 31(10), 721-730.
[13] Islam, S. M., Hussain, R. R., & Morshed, M. A. Z. (2012). Fiber-reinforced concrete incorporating locally available natural fibers in normal-and high-strength concrete and a performance analysis with steel fiber-reinforced composite concrete. *Journal of composite materials*, 46(1), 111-122.
[14] Ali, M., Liu, A., Sou, H., & Chouw, N. (2012). Mechanical and dynamic properties of coconut fibre reinforced concrete. *Construction and Building Materials*, 30, 814-825.
[15] Elsaid A, Dawood M, Seracino R, Bobko C. Mechanical properties of kenaf fiber reinforced concrete. *Constr Build Mater* 2011;25(4):1991–2001
[16] Peled A, Bentur A. Geometrical characteristics and efficiency of textile fabrics for reinforcing cement composites. Cem Concr Res 2000;30(1):781–90
[17] https://myscope.training/legacy/xrd/practice/prep/
[18] Epp, J. (2016). X-ray diffraction (XRD) techniques for materials characterization. In *Materials characterization using Nondestructive Evaluation (NDE) methods* (pp. 81-124). Woodhead Publishing.
[19] Segal, L. G. J. M. A., Creely, J. J., Martin Jr, A. E., & Conrad, C. M. (1959). An empirical method for estimating the degree of crystallinity of native cellulose using the X-ray diffractometer. *Textile research journal*, 29(10), 786-794..
[20] Liu, W., Mohanty, A. K., Drzal, L. T., Askel, P., & Misra, M. (2004). Effects of alkali treatment on the structure, morphology and thermal properties of native grass fibers as reinforcements for polymer matrix composites. *Material Science and Engineering* 39(3), 1051-1054.

[21] Hosur, M., Maroju, H., & Jeelani, S. (2015). Comparison of effects of alkali treatment on flax fibre reinforced polyester and polyester-biopolymer blend resins. *Polymers and Polymer Composites*, 23(4), 229-242.

[22] Punyamurthy, R., Sampathkumar, D., Srinivasa, C. V., & Bennehalli, B. (2012). Effect of alkali treatment on water absorption of single cellulosic abaca fiber. *BioResources*, 7(3), 3515-3524.

[23] Fiore, V., Di Bella, G., & Valenza, A. (2015). The effect of alkaline treatment on mechanical properties of kenaf fibers and their epoxy composites. Composites Part B: Engineering, 68, 14-21..

[24] Li, Z., Zhang, X., Fa, C., Zhang, Y., Xiong, J., & Chen, H. (2020). Investigation on characteristics and properties of bagasse fibers: Performances of asphalt mixtures with bagasse fibers. *Construction and Building Materials*, 248, 118648.

[25] Pandey, A., & Kumar, B. (2019). Effects of rice straw ash and micro silica on mechanical properties of pavement quality concrete. *Journal of Building Engineering*, 26, 100889.

[26] Mansor, M.R.; Mastura, M.T.; Sapuan, S.M.; Zainudin, A.Z. *The Environmental Impact of Natural Fiber Composites through Life Cycle Assessment Analysis*; Elsevier: Amsterdam, The Netherlands, 2018

[27] Sahu, P., & Gupta, M. K. (2018, December). Mechanical, thermal and morphological properties of sisal fibres. In IOP conference series: materials science and engineering (Vol. 455, No. 1, p. 012014). IOP Publishing.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

DIFFERENT TECHNIQUES FOR ENHANCING DURABILITY OF NATURAL FIBERS IN CEMENTITIOUS COMPOSITES - AN OVERVIEW

[a] Arif Ahmadzai
a: Field engineer at Sharq Afghan Shaheen construction companyemail:arifkhan0785054@gmail.com

Abstract- Natural fibers in cementitious composites (NFCC) have been gaining popularity universal due to their application in low cost construction processes. In spite of the fact that there is wide scope of opening for natural fibers in cementitious composites, their long term durability performance under various exposure environmental conditions is still a question with unstable answer. Since several decades researchers have been working to dominate the durability issue by providing a correct technology for NFCC, actually possible product for different applications. This overview reveals a light on various durability mechanism of natural fibers and NFCC under several exposure environmental conditions, different techniques are accepted for enhancing the durability of natural fibers and NFCC. The durability improvement is encountered to be premier with the composites containing cementitious material than in plain fiber cement composites. Furthermore, incorporation/use of treated fibers in the treated matrix shows superior performance under durability testing. However, many studies necessity to be improved to confirm the existent improvement on durability of the natural fibers in cementitious composites.

Keywords- Different Techniques, Enhancing Durability, Natural Fibers In Cementitious Composites

1 INTRODUCTION

Measurement of aging durability of natural fibers in cementitious composites, specimens for flexure test were placed into hot water saturated with lime and kept at a constant temperature of 70 ± 2 C° and tested according to ASTM C1560-03 [1]. Accelerated aging test was performed for Vegetable fibers in natural weathering, specimens were placed into water for 170 min at 20 ± 5 C°, and then 10 min after they were dried for 170 min at 70 ± 5 C° in an oven. Another cycle is started after 10 min, samples were immersed 200 accelerated aging cycles and test was recommended according EN 494 standard [2-3]. Water absorption test was performed at flax fiber, first sample was dried in a dehydrating oven at 40 C° for three days, and then sample was immersed into distilled water at a room temperature. This test was stopped after 30 days, at each cycle, calculated weight of the fiber at dried and saturated conditions respectively. The related water absorption was calculated by (saturated weight minus dried weight) divided dried weight [4]. Jute fiber durability test was performed, first fiber was soaked in 100 C° boiling water for 1h and then absorption moisture was evaporated for 2h at room temperature to fix specimens and then durability test was performed [5]. Environmental aging tests were performed by Bamboo fiber reinforced polymer and Bamboo Glass reinforced polymer, samples were immersed in water at 25 C° and at 75 C° for 6 months 3 months respectively. Tensile tests were performed at the end of 6 months and 3 months for samples which immersed at 25 C° and 75 C° respectively [6]. Durability tests of vegetable fibers mortar composites were performed on the basis of flexure properties before and after exposures to various environmental conditions. Samples were placed to three various environmental conditions, first set of samples were placed into water at 18 C° temperature, second set of samples were placed into London natural weathering conditions started from December 1994, and third set of samples were placed into wetting and drying cycles. Samples were tested after 6 months. Wetting and drying period was 7 days, samples were placed into water for a day at 18 C°, and 6 days for drying at 23 C° and 40% relative humidity [7].

Natural fibers are used in cementitious composites to enhance the mechanical properties of the cementitious composites. Cementitious composites properties are reduced due to their durability problems, such as occur in aggressive and alkaline environments [31]. In durability conditions, mechanical properties of the NFCC were reduced like shear strength, flexural strength and flexural modulus [8]. Some natural fibers maintained their tensile strength when fully wetted at room temperature in humidity conditions, but others showed a significant decrease in tensile strength [9]. Sisal fiber has best mechanical properties with low density, however it has poor durability in alkaline environment, such as in cement matrix [10]. Flax fiber capability to moisture absorption, its durability resistance in humid environment is limited thus its application is restricted to semi-structural or non-structural interior products [11]. At moisture absorption of natural fibers bond in a polymeric matrix, the fibers hydro expansion can lead to reduction of the strength and stiffness, matrix cracking, over time associate losing of mass with water entrance [12]. Due to fiber mineralization and alkali attack in humidity environment is subjected to post-cracking strength and toughness reduction of the natural fiber reinforced composites [13]. Cellulose fiber reinforced cement composites gain strength and stiffness, but they are sensitive to moisture effects and they lost their durability with time [14]. Sisal and Coconut fibers reduced their strength when immersed in alkaline dilution, and date palm reinforced concrete had low durability performance when immersed in alkaline dilution [15]. In spite of vegetable natural fibers advantages, their production of cement base composites are limited due to their durability problems in environmental condition [16]. Sisal fiber durability problems are associated with increasing fibers fracture and decreasing in fiber pull out due to fibers attack by alkali, fiber mineralization, immigration of hydration products to lumens and fiber volume variation because of their superior water absorption [17, 32]. Fan palm fibers width were decreased when it were treated, using alkali treatment chemical method from 1 mm to a range between 0.6 and 0.9 mm [28]. The durability of natural fibers were related both external and internal environments, internal alkaline environment in cementitious matrixes were reduced the durability of natural fibers [30]. Short, discrete coconut fibers into high strength concrete reduced sulfate attacked on marine structures. Coconut fibers into high strength concrete retained crack propagation on marine structures, and it improved long term durability of marine structures compared to high-strength plain concrete, but degradation affected on fibers. To protect coconut fibers from degradation, treatment of the fibers is necessary [25].

Enhancing durability of NFCC were the modification of the matrix composites to remove or reduce the alkalinity of the composition [16]. Durability were improved of the natural fibers in cementitious composites by modified fiber surface by physical or chemical treatments to enhance their durability in cementitious composites [16]. Increasing durability of natural fibers in cementitious composites, a good solution is the replacement of Portland cement 30% and 20% by metakaolin and calcined crushed clay waste brick respectively [18]. Improving durability of sisal fiber composites by the help of matrix carbonation and soaking of the fibers in slurries silica fume [17]. Long term durability of natural fibers were enhanced by lower production of Calcium Hydroxide (only 50% normal Portland cement), reduced CO_2 transpiration, and a sustainable and economical approach [19]. To improve the durability efficiency of natural fibers in cementitious composites several investigation were done including fibers saturation with blocking agents and water-repulsive agents, matrix sealing, decreasing alkalinity of the matrix, and fibers and matrix modification [20]. Saturated vegetable fibers in mortar reinforced composites had better durability behavior than in those with unsaturated fibers, colophony was very effective in the reduction of fibers mineralization in exposure conditions for saturated and unsaturated fibers [21]. Enhancement of the durability of natural fibers in cementitious composites are the sealing dry composites or coating of the fibers to prevent the effect of the water basically alkalinity, and decreasing the alkalinity in matrix by improving low alkaline binders [21, 33]. Calcium-aluminate cement with 10% metakaolin content leaded to high durability of flax fiber reinforced composites materials [22]. Sisal fiber durability improved by treated of fiber by Acetic and Acetic Anhydride, and environmental condition had less effect on treated sisal fiber compared to untreated fiber [1]. Date palm fibers were treated by immersion in NaOH and $Ca(OH)_2$ solutions, and showed better tensile strength and stiffness compared to untreated fibers thus it improved the durability of mortar matrix [29].Different techniques are considered to enhance durability of natural fibers such as fibers surface modification and matrix modification, replacement of the part of Portland cement with silica fume, slag and metakaolin, and early water curing with rich CO_2 environment. This study will help to understand different techniques to enhance durability of natural fibers in cementitious composites.

2 FACTS ABOUT REDUCING DURABILITY OF NATURAL FIBERS IN CEMENTITIOUS COMPOSITES

2.1 Specification

Measuring aging durability of natural fibers in cementitous composites, two set of specimens were tested under bending. Treated and untreated specimens were prepared from 77.2% of Portland cement type CPV-ARI, 12.8% of ground carbonated material industrialized from agricultural application, and 10% unrefined unbleached eucalyptus cellulosic pulp. Fibers were treated by slurry dewatering technique. Specimens were cured in two different conditions, Non-carbonated curing (NCC), and Accelerated carbonation curing (ACC). NCC specimens for first two days were kept in pertaining to weather chamber at 60 C° temperature and 90% relative humidity, and then kept under 25 C° in saturated curing until 28 days. ACC specimens were kept for two initial days in pertaining to weather chamber at 60 C° temperature and 90% relative humidity, and then applied accelerated carbonation by releasing CO_2 cycles into the chamber until the saturation of the total environment. These cycles were performed until the absorption of the carbonation, and then specimens were kept under 25 C° in saturated curing until 28 days. All specimens were kept for 1 year in two different environmental conditions, natural weathering condition of the State of Sao Paulo, Brazil and soaking and drying cycles in laboratory. At soaking and drying cycles, specimens were placed into water for 170 min at 20 ± 5 C°, and then 10 min after they were dried for 170 min at 70 ± 5 C° in an oven. Another cycle was started after 10 min, samples were placed 200 and 400 soaking and drying cycles respectively and then were tested according EN 494 standard [2, 3].

Table 1: Natural weathering condition of the Sao Paulo Brazil, and Soaking and drying conditions for test specimens

Set/Time	natural weathering, and soaking and drying conditions	
	28 days	1 year
Natural weathering Condition	First 2 days water curing at 60 C° and 90% RH; Reaming water curing Until 28 days at 25 C°	State of Sao Paulo, Brazil Annual RH = 84%; Annual temperature = 21.4 C° Annual rainfall = 2310 mm
Soaking and drying Condition	First 2 days water curing at 60 C° and 90% RH; Reaming water curing Until 28 days at 25 C°	Soaking at 20 ± 5 C° for 170 min Drying at 70 ± 5 C° for 170 min 200 soaking and drying cycles, and 400 soaking and drying cycles

2.2 *Technology Involve*

Universal Testing Machine Emic DL - 30000 was used to perform the bending test. It has two spans upper and lower. Upper span and lower span lengths were 45 mm and 135 mm respectively. For the determination of the mechanical properties the deflection rate was 1.5 mm/min. A deflectometer was used in the middle of span to collect deflection during the test [2, 20].

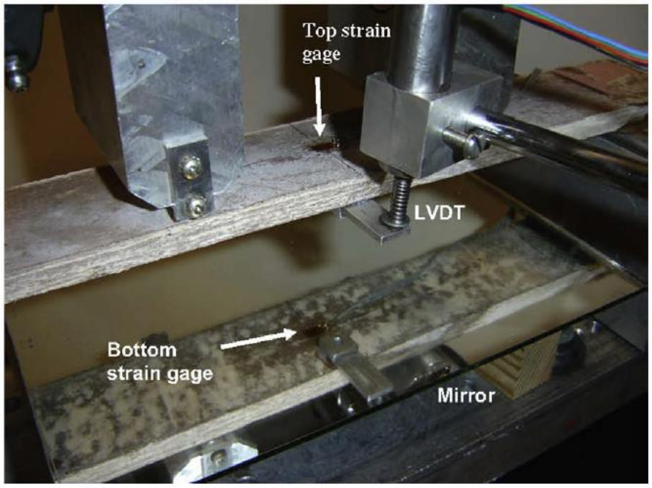


Fig. 1. Four point bending test [19].

2.3 *Method implementation*

For determination of mechanical properties, (1)-(3) equations were used as described by Tonoli et al in detail [26, 27].

$$MOR = \frac{p_{max}.L_v}{b.h^2} \quad (1)$$

$$LOP = \frac{P_{lop}.L_v}{b.h^2} \quad (2)$$

$$MOE = \frac{276.L_v{}^3}{1296.b.h^3}m \qquad (3)$$

Where *MOR* is the modulus of rupture, *LOP* is the limit of proportionality, *MOE* is the modulus of elasticity, P_{max} is the maximum load value, L_v is major span, P_{lop} is the load at the upper point of the linear portion of the load-deflection curve, *m* is the tangent of the slope angle of the load vs deflection curve during elastic deformation, and *b* and *h* are the specimen width and depth respectively.
For the determination of the specific energy as the total absorbed energy during the test divided the cross sectional area of the specimen. Absorbed energy was calculated by load-deflection curve integration up to the point in which 30% reduction of the maximum load occurring in a load currying capacity [2].

3 DURABILITY METHOD IN CEMENTITIOUS COMPOSITES

Evaluation of the durability performance of the natural fibers in cementitious composites, laminates were created and tested under flexural subjected to before and after an accelerated aging. Each sample was prepared from 5 layers nonwoven flax fibers saturated in paste matrix, and piled after the immersion in a drilled and subjected to a vacuum in an absorption chamber. Then samples were compressed under 3.5 MPa and cured at 20 ± 1 C° and 90 relative humidity for 28 day, this principle for the lamination of 12 mm thickness (Fig. 2). Two plates were prepared of 300 x 300 mm^2 per sample composition. Half of the specimens were tested after 28 days curing and remaining half were tested after the process of accelerated aging after the curing of 28 days. Accelerated aging had 250 wetting and drying cycles performed in an automatic chamber (CCI Calidad, Span). Every cycle was started with specimens immersion into water for 3 h at 20 C° and then dried for 3 h at 20% relative humidity and 60 C°. Flexural test was performed with an Incotecnic Universal Testing Machine, equipped with a 3 kN load cell and a 4-point bending device with 270 mm and 90 mm support span and load span respectively. Test was performed at rate of 5 mm/min and mechanical properties were determined from the curves [22].

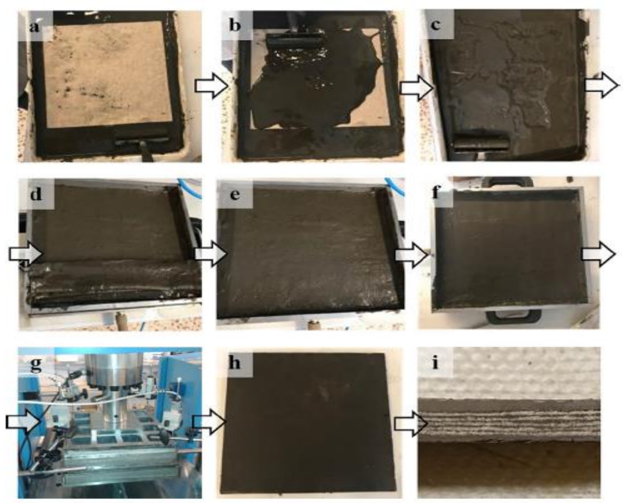


Fig. 2: composite samples preparation. (a)-(c) nonwoven fabric immersion process in cement paste. (d)- (f)

For the elimination of excess water vacuum is applied, after the placing of reinforcement into the mold. (g) 5 layers of cement-nonwoven-cement layer are prepared up to reach into the required thickness, and then under a higher pressure the compaction is currying. (h) Before curing composite specimens. (i) Cutting of the samples showing nonwoven layers [22}.

Investigation was done on sisal and coconut fibers reinforced mortars. Control specimen was preferred from ordinary Portland cement mortar matrix, specimens were reinforced with short 25 mm sisal or coconut untreated distributed fibers and long 375 mm sisal untreated aligned fibers. Fiber friction was 3%, 2% short fibers and 1% long fibers were used in investigation. For the better incorporation of the fibers in matrix long fibers were immersed for 10 min in slurry silica fume and then dried for 15 min in air. Four different types of treated specimens were preferred, one set of specimens were preferred from (0.6OPC+0.4slag) 40% ordinary Portland cement (OPC) replaced with slag, another set of specimens were preferred form (0.9OPC+0.1silica fume) 10% OPC replaced with silica fume. Third set of specimens were preferred from (0.6OPC+0.4slag) and fibers were immersed in slurry silica fume, fourth set of specimens were preferred from (0.9OPC+0.1silica fume) and fibers were immersed in slurry silica fume. Test specimens, each measuring was 400 x 100 x 15 mm, and tested under bending after 28, 109, and 365 days respectively. The durability of the vegetable fiber reinforced mortar composites were measured before and after exposured to different environments on the basis of flexural properties. Results were indicated that increasing early water curing period decreasing the carbonation depth. Fibers were treated in slurry silica fume to create around the fiber low PH value to reduce or avoid alkaline attack and for the transportation of calcium products to the fibers. OPC was replaced 40% and 10% with slag and silica fume respectively, for the treatment of the matrix to reduce alkalinity and improved the durability of the matrix. Early cure of vegetable fiber reinforced mortar composites in a rich CO_2 environment is another way to improve the durability of the matrix with aging. The durability of the matrix was improved by the decreasing the alkalinity of the matrix [7]. The mechanical properties of the matrix were increased with treatment of the fibers by silica fume and slag. Table 2 showed that post-crack flexural strength of the matrixes were enhanced by the replacement of the ordinary Portland cement with slag and silica fume, and also it enhanced by the immersion (treatment) of the fibers in slurry silica fume.

Table 2: Comparison of post-crack flexural strength for different specimens

Mix	Mix proportions of mortar (By weight) (Cement: sand: water)	Treatment applied	Fiber types	Volume Friction V_f %	Condition: 46 wet-dry Cycles, post-crack Flexural strength (MPa) After 322 days
M1S2S1	1:1:0.4	Non-treated	Sisal	S2S1=3	3.06
M1C2S1	1:1:0.4	Non-treated	Coconut + Sisal	C2S1=3	3.79
M1slagS2S1	(605 OPC+40% slag):1:0.4	Replace 40% OPC With slag	Sisal	S2S1=3	2.9
M1msS2S1	(90% OPC+10% MS):1:0.46	Replace 10% OPC With silica fume	Sisal	S2S1=3	4.44
M1S2S1i	1:1:0.4	Aligned immersion of fiber In slurry silica fume	Sisal	S2S1=3	5.06
M1slagS2S1i	(60% OPC+40% slag):1:0.4	Replace 40% OPC with Slag + fiber immersion In slurry silica fume	Sisal	S2S1=3	5.12
M1S2S1cab	1:1:0.4	109 days carbonation	Sisal	S2S1=3	6.39
M1C2S1cab	1:1:0.4	109 days carbonation	Coconut + Sisal	C2S1=3	5.39

4 LESSON LEARNT

Result showed that composites which were made from non-dried flax fibers and resin were low sensitivity to moisture compared to those composites which were made form dried flax fibers [34]. Non-dried flax fibers composites were enhanced the flexural strength and modulus of elasticity compared to dried flax fibers composites [34]. Replacement 15% cement with silica fume and 8% cellulose fibers content were improved the mechanical strength and durability of the cement paste composites for bore well [35]. Cellulose fibers were enhanced the mechanical strength of the matrix, and replacement of the cement with silica fume enhanced the durability of cement paste composites [35]. Palmyra natural fibers were treated by 4% stearic acid to improve the durability. Experiment showed that treatment of the fibers by stearic acid lead to reduce moisture diffusivity and enhanced the durability of the Palmyra natural fiber composites under different wet environment and temperature [36]. Investigation was done on three different flax fiber reinforced composites, untreated, pre-treated, and treated by zirconium dioxide coating. Fibers were embedded in cement paste and tested after 90 days, untreated and pre-treated fibers retained 41% and 31% their initial strength respectively, while zirconium dioxide treated fibers retained 96% initial strength. Fibers treated by zirconium dioxide improved their durability in cementitious composites [37]. Treated and untreated jute fibers were investigated, fibers were treated combined alkali modified (0.5% NaOH, 24 h) and polymer modified (0.125% carboxylated styrene butadiene rubber) successfully. Treated fibers had more tensile strength compared to untreated fibers in different exposure conditions [23].

Vegetable fibers durability performance in cementitious composites can be increased with curing conditions. Investigation showed that increasing initial water curing period, decreasing the carbonation depth in vegetable fiber composites matrix. Thus increasing early water curing period in a rich CO_2 environment can be improved the durability of vegetable fibers in cementitious composites with aging. The durability of natural fibers cementitious composites were enhanced with treatment of the fibers by slurry silica fume. Another way to improve the durability of natural fibers in cementitious composites is the replacement of the ordinary Portland cement 40% and 10% with slag and silica fume respectively. Slag and silica fume reduce the PH value of the matrix, thus it reduce the alkalinity of the matrix and improve the durability in different environmental conditions. Vegetable fibers durability were enhanced in reinforced cement mortar with saturation of the fibers, because colophony was effective in the reduction of the fibers mineralization in exposure conditions. Coating of the vegetable fibers with different chemical material also enhanced the durability of the natural fibers in cementitious composites.

A good solution to enhance the durability of natural fibers in cementitious composites is the replacement of Portland cement 30% and 20% by metakaolin and calcined crushed clay waste brick respectively. Durability of the natural fibers were enhanced with surface modification of the fibers and matrix modification. Fibers surface modification was done with saturating of the fibers by slurry silica, stearic acid, silane, natural resins, bariumnitrate, formine, etc. and matrix modification was done by replacement of partially ordinary Portland cement with pozzaolanic materials such as fly ash, slag, metakaolin, silica fume, etc. Alkaline treatment of the fibers showed better performance in reduction of water absorption capacity, and modified surface of the fibers. Usually alkali treatments of the fibers are done with immersion of the fibers in NaOH, KOH, Ca(OH)2 etc. solutions. One of the investigation showed that treatment of the hemp fibers in NaOH solution enhanced the flexural strength 39% compared to those hemp fibers which were untreated. Durability of the natural fibers can be enhanced with beating and bleaching of the fibers, beating and bleaching is a type of mechanical surface treatment of the fibers. Treatment of the wood fibers with silane contents had better durability performance with aging, and also this type treatment improved the compressive strength and compressive toughness compared to untreated wood fibers. Pulping of the natural fibers is another technique to enhance the durability of the matrixes. Pulping removes the lignin (a material causing degradation effect) in greater extent and provides better durability and mechanical behavior for the composites.

5 CONCLUSION

Various types of natural fibers such as sisal, coir, banana, hemp, jute, kenaf, rice husk, human hair, horse hair, etc are widely used in low cast construction. Different unwell effects associated with natural fibers due to water connectivity and degradation under alkaline solutions. These ill effects cause the natural fibers to be little used for long service life under different climatic conditions. There are several techniques to improve the durability of natural fibers in cementitious composites.

- One of a good solution to enhance the durability of natural fibers in cementitious composites is the replacement of a part of Portland cement with metakaolin and calcined crushed clay brick.
- Durability of the natural fibers can be enhanced with surface modification of the fibers and matrix modification.
- Fibers alkaline treatment modify fibers surface, reduce fibers water absorption capacity, and improve fibers durability in matrix.
- Early curing in a rich CO_2 environment can be improved durability of the vegetable fibers in cementitious composites.

This study demonstrates different techniques to enhance durability of natural fibers in cementitious composites. It shows, that natural fiber cementitious production will have been found better options for enhancing durability for different civil engineering applications.

ACKNOWLEDGMENT

The author is would like to thank for his gratefully acknowledge Dr. Engr. Majid Ali for his guidance and help in this an overview study.

REFERENCES

[1] M. D. de Klerk, et al, "Durability of chemically modified sisal fiber in cement-based composites", *Construction and Building Materials*, 2020.

[2] A. E. F. S. Alemida, "Improved durability of vegetable fiber reinforced cement composite subject to accelerated carbonation at early age", *Cement and Concrete Composites*, 2013.

[3] G. H. D Tonoli, et al, "Performance and Durability of Cement Based Composites Reinforced with Refined Sisal Pulp", *Materials and Manufacturing Processes*, 2007.

[4] A. Moudood, "Environmental effects on the durability and the mechanical performance of flax fiber/bio-epoxy composites", *Composites Part B: Engineering,* 2019.

[5] J. M. Park, et al, "Interfacial evaluation and durability of modified Jute fibers/polypropylene (PP) composites using micromechanical test and acoustic emission", *Composites Part B: Engineering*, 2008.

[6] M. M. Thwe, and K. Liao, "Durability of bamboo-glass fiber reinforced polymer matrix hybrid composites", *Composites Science and Technology*, 2003.

[7] R. D .T. Filho, et al, "Development of vegetable fiber–mortar composites of improved durability", *Cement and Concrete Composites*, 2003.

[8] A. K. F. Dilfi et al, "Effect of Surface Modification of Jute Fiber on the Mechanical Properties and Durability of Jute Fiber Reinforced Epoxy Composites", *Polymer composites,* 2018.

[9] R. Ramadan et al, "Short-term durability of hemp fibers", *Procedia Engineering,* 2017.

[10] J. Wei, S. Ma, and D.G. Thomas, "Correlation between hydration of cement and durability of natural fiber-reinforced cement composites", *Corrosion science,* 2016.

[11] V. Fiore et al, "Effect of external basalt layers on durability behavior of flax reinforced", *Composites Part B: Engineering*, 2016.

[12] S. A. Miller et al, "Integrating durability-based service-life predictions with environmental impact assessments of natural fiber–reinforced composite materials", *Resources, Conservation and Recycling*, 2015.

[13] R. S. Olivito, O.A. Cevallos and A. Carrozzini, "Development of durable cementitious composites using sisal and flax fabrics for reinforcement of masonry structures", *Materials and Design,* 2014.

[14] P. Soroushian, J. P. Won, and M. Hassan, "Durability characteristics of CO2-cured cellulose fiber reinforced cement composites", *Construction and Building Materials*, 2012.

[15] Omoniyi, T. E, and Akinyemi B.A., "Durability based suitability of bagasse-cement composite for roofing sheets", *Journal of civil Engineering and Construction technology,* 2012.

[16] J. Claramunt et al, "The hornification of vegetable fibers to improve the durability of cement mortar composites", *Cement and Concrete Composites*, 2011.

[17] R. D .T. Filho, et al, "Durability of compression molded sisal fiber reinforced mortar laminates", *Construction and Building Materials,* 2009.

[18] F. D. A. Silva, et al, "Physical and mechanical properties of durable sisal fiber–cement composites", *Construction and building Materials*, 2010.

[19] F. D. A. Silva, B. Mobasher, and R. D. T. Filho, "Cracking mechanisms in durable sisal fiber reinforced cement composites", Cement and Concrete Composites, 2009.

[20] R. D. T. Filho, et al, "Durability of alkali-sensitive sisal and coconut fibers in cement mortar composites", *Cement and Concrete Composites*, 2000.

[21] M. F. Canovas, N. H. Silva, and G. M. Kawiche, "New economical solutions for improvement of durability of Portland cement mortars reinforced with sisal fibers", *Materials and Structures,* 1992.

[22] M. Ramirez, et al, "Evaluation of the mechanical performance and durability of binary blended CAC-MK/natural fibe composites", *Construction and Building Materials,* 2020.

[23] S. P. Kundu, et al, "Effectiveness of the mild alkali and dilute polymer modification in controlling the durability of jute fiber in alkaline cement medium", *Construction and Building Materials, 2018.*

[24] H. J. Lee, and W. Kim, "Long term durability evaluation of fiber reinforced ECC using wood based cellulose nanocrystals", *Construction and Building Materials,* 2020.

[25] M. Ramli, W. H. Kwan, and N. F. Abas, "Strength and durability of conconut fiber reinforced concrete in aggressive environments", *Construction and building Materials*, 2013.

[26] G.H.D. Tonoli, et al, "Cellulose modified fibers in cement based composites", *Composites: Part A,* 2009.

[27] G.H.D. Tonoli, et al, "Hybrid Reinforcement of Sisal and Polypropylene Fibers in Cement-Based Composites", *Journal of Materials in Civil Engineering,* 2011.

[28] M. Machaka, and A. Elkordi, "Experimental study of the effect of adding fan palm fibers on concrete durability exposed to severe environments", *2 ndInternational Conference on Bio-based Building Materials& 1st Conference on ECOlogicalvalorisation of GRAnular and FIbrous materials,* 2017.

[29] N. G. Ozerkan, et al, "Mechanical performance and durability of treated palm fiber reinforced mortars", *International Journal of Sustainable Built Environment*, 2014.

[30] G. Ramakrishna, T. Sundararajan, and S. Kothandaraman, "Evaluation of durability of natural fiber reinforced cement mortar composite – A new approach", *ARPN Journal of Engineering and Applied Sciences*, 2010.

[31] H. C. Lima, et al, "Durability analysis of bamboo as concrete reinforcement", *Materials and Structures,* 2008.

[32] F. A. Silva, et al, "Mechanical behavior and durability of compression moulded sisal fiber-cement mortar laminates", *1st International Conference Textile Reinforced Concrete,* 2006.

[33] V. Agopyan, and V. M. John, "Durability evaluation of vegetable fiber reinforced materials: sisal and coir vegetable fibers as well as those obtained from disintegrated newsprint found to be the most suitable fibers for building purposes", *Building Research and Information*, 1992.

[34] M. M. Lu, and A. W. V. Vuure, "Improving moisture durability of flax fiber composites by using non-dry fibers", *Composites: Part A*, 2019.

[35] X. W. Cheng, et al, " A new approach to improve mechanical properties and durability of low-density oil well cement composite reinforced by cellulose fibers in microstructural scale", *Construction and Building Material*, 2018.

[36] D. Jain, et al, "Comparison of different hydrophobic treatments for the durability improvement of palmyra natural fiber composites under hydrothermal aging environments", Journal of natural fibers, 2019.

[37] L. Boulos, et al, "The effect of a zirconium dioxide sol-gel treatment on the durability of flax reinforcements in cementitious composites", Cement and Concrete Research, 2019.

ONE-PART GEO-POLYMER CONCRETE USING WHEAT STRAW ASH AND BENTONITE

Asfandyar khan[a], Najmul Hassan[b], Muhammad Faisal Javed[c], Mir Hamza[d], Tamim Yousafzai[e].
Corresponding Author. BS student, Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus. Email: Asfand3415@gmail.com
BS student, Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus
Email: najmulhassan823@gmail.com
Assistant Professor, Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus. Email: arbabfaisal@cuiatd.edu.pk
BS student, Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus.
BS student, Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus.

Abstract Geopolymer concrete (GC) is considered as environmentally friendly concrete as compared to traditional concrete. As the formation of GC involves the addition of liquid Alkali Activated Materials (AAM) which is hazardous to the human skin. Hence, this research has been conducted to use activators (sodium silicate and sodium aluminate) in powder form along with Wheat Straw Ash (WSA) and bentonite for making GC. Different combinations were used for making mortar as 100% Bentonite, 20% WSA, and 80% Bentonite, 30% WSA, and 70% Bentonite. In all these ratios 10% sodium silicate in each sample with w/b of 0.4. Bentonite and WSA are used because these materials are pozzolanic in nature and can replace cement. Samples containing 80% WSA and 20% bentonite with a w/b ratio of 0.3, 0.4 and 0.5. 0.4 yields the highest compressive strength of 26 MPa. Hence, this ratio can be used in the future to further explore the behavior of GPC.

Keywords- Ordinary Portland Cement (OPC), Geo-Polymer Concrete (GC), Alkali Activated Materials (AAM), Wheat Straw Ash (WSA), Carbon Dioxide (CO_2), Super Plasticizer (SP), Sodium Silicate (Na_2SiO_3).

1 INTRODUCTION

Construction industries are increasing day by day due to an increase in the demand for the development of infrastructure. In today's world concrete is widely used as a construction material due to its low cost, high strength, mouldability and high-temperature resistance which requires low or no maintenance. During the formation of concrete, the essential component (cement) is added in it which affects our environment by emitting CO_2 and Nitrogen oxides [1]. From previous studies, it can be concluded that by the production of 1 ton of cement release approximately 1 ton of CO_2 to the atmosphere [2], this amount adds up to 7% of CO_2 which is contributed towards global warming. Another major issue that contributes towards global warming is the burning of crop's waste into ashes. So, to tackle this issue the researchers have worked and suggested that instead of disposing of the waste it shall be incorporated into concrete that could reduce the negative impact of CO_2 on the environment. Besides, it could add to the internal properties of concrete (micro-structure properties) [3]. To minimize the usage of cement, alternatives solution is founded by researchers such as Geo-Polymers are introduced. It is formed by utilizing the waste materials**.** The main constituents of Geopolymer are Silicon and Aluminum which are provided by thermally activated natural materials (kaolinite) or industrial by-products such as Fly Ash, Rice-Husk Ash, Wheat-Straw Ash and alkaline activating solutions which polymerize these materials into molecular chains and network to create a hardened binder. **Wheat straw** is a byproduct of wheat that is commonly disposed of on a large scale. Even only in Pakistan for every 4 tons of wheat grain, 6 tons of **wheat straw is produced [4].** The global estimated production of wheat from 2016 to 2017 was about 750 million tons **[5]. WSA possess pozzolanic properties which is found by performing** X-Ray Fluorescence (XRF) test that shows that WSA contain amorphous Silica and Alumina and has the potential to be used as a pozzolanic material, which is capable to replace cement partially [6]. Beside that it gives high compressive strength. So controlled burning of wheat straw is preferred at 600°C and at this temperature it showed best pozzolanic performance [6].

Figure 1: Flow chart of Wheat-Straw Ash

Bentonite is the commercial name of a whole range of natural clays with a high-water absorption capacity. Bentonite may contain a variety of accessory minerals in addition to montmorillonite due to its pozzolanic property [7], it can also be used in addition to WSA.

Figure 2: Bentonite

One-part Geo-polymer concrete is new technique in Geopolymer field in which activators are used in powder form. In our research work geopolymer is formed by using waste of agricultural material such as WSA with the combination of Bentonite in order to replace cement fully.
Research significance of our research work are:

- To contribute in reducing the CO_2 emissions by cement production.
- To achieve durable and workable geopolymer concrete based upon WSA and Bentonite.
- To make the best use of waste material in concrete for an eco-friendly and sustainable environment.

Many researchers have worked on a one-part geopolymer by substituting different alumina-silicate activators partially with cement, however no detailed and systematic studies have been designed on WSA and Bentonite fully replacing cement. In this research work we are substituting WSA and Bentonite with cement fully.

2 EXPERIMENTAL PROCEDURES

2.1 Testing

Testing has been divided into two phases; the first phase included XRF while the second phase included compressive strength test.

2.2 First phase Testing

a. X-ray fluorescence (XRF)

XRF test will be performed to determine the qualitative and quantitative elemental composition of WSA. The WSA particles would be excited by the primary X-ray source and each element present in the WSA sample produces a set of characteristic fluorescent X-rays that are unique for a specific element.

2.3 *Second Phase Testing*

b. Compressive Strength Test

For assessment of the compressive strength of the mortar, samples were cast in cubes of the standard dimensions of 2in x 2in x 2in. The sample, after its desired curing period, was placed in a Universal testing machine with its hardened face-up, on the plates of the machine. The sample was placed align to the axis of the machine. The final load was recorded which was divided by the cross-sectional area to compute the compressive strength. Moreover, for a single test, an average of three samples was taken.

3 RESEARCH METHODOLOGY

a. *Materials*

b. *The summary of all the materials that have been used throughout the testing has been given below:*

c. *Fine Aggregate*

d. *The fine aggregate that has been used was taken from a quarry near COMSATS University Islamabad, Abbottabad Campus. The sieve analysis was performed using ASTM C136-01. The sieve analysis gave a Fineness Modulus of 2.64.*

3.1 *Wheat Straw Ash:*

The Wheat Straw Ash that has been used, as a replacement of Cement. Wheat Straw was acquired from Abbottabad, Khyber Pakhtunkhwa Pakistan. The Wheat Straw was burned at 600 ºC for 2 hours in Muffle furnace to obtain Ash then it was grinded for 2 hours in grinding mill.

Figure 3: Wheat Straw Ash at 600 ºC

3.2 *Bentonite:*

Along with Wheat Straw Ash, bentonite was also used as a replacer for Cement. Bentonite was acquired from Azakhel Waziristan Khyber Pakhtunkhwa Pakistan. Calcium Bentonite was used. Calcium Bentonite first was ground to powder form and then was passed from sieve no 200.

3.3 *Mixing Water:*

The water that has been incorporated into mortar was the ordinary tap water of COMSATS University Islamabad, Abbottabad Campus.

3.4 *Sodium Silicate (Na_2SiO_3):*

During the whole research, Na_2SiO_3 in dry powder form was used. The anhydrous form of Na_2SiO_3 was used. The Na_2SiO_3 is Alkali-Activated Activator which is used in sample preparation to activate the Silica and Alumina present in the WSA and Bentonite. The properties of Na_2SiO_3 are given below:

Table 1: Properties of sodium silicate (Na_2SiO_3)

Colour	white
Form	Powder (Anhydrous)
Molecular weight	122.063 g/mol

3.5 *Super-plasticizer*

After mixing all material along with water, the sample did not attain enough workability, so to enhance workability super-plasticizer was added.

3.6 *Mix Proportion:*

To perform the whole experimentation, a mix of 2kg sample was prepared on a ratio of 1:1 (1 part of WSA and Bentonite and 1 part of sand). Initially, the water-binder (w/b) ratio was 0.3 and was increased gradually. The activator Na_2SiO_3 has been used as 10% of the total sample mix. The complete mix design has been summarized in Table below

Table 2: Mix Design of Geopolymer Concrete

Bentonite (%)	**WSA (%)**	**Activator (%)**	**WSA (g)**	**Bentonite (g)**	**Na_2SiO_3 (g)**	**Sand (g)**	**Water (g)**	**SP (%)**	**Water/Binder Ratio (w/b) (%)**
0.7	0.3	10	300	700	200	1000	300	3	0.3
0.2	0.8	10	800	200	200	1000	400	2	0.4
0.1	0.9	10	900	100	200	1000	500	2	0.5

3.7 *Mixing*

After adding all materials, they were dry mixed for 20 minutes in Mixer, after dry mixing water was added and again mixed for 5 minutes. After that it was found that the sample was not enough for work. So, to increase workability 2% super-plasticizer was added, and then the sample was mixed for 5 minutes to achieve desire workability

Figure 4: Sample of Mortar and Mixer Machine

3.8 *Sample Curing*

3.9 *Heat Curing*

After casting samples, moulds were placed in the oven-drying machine at 70 °C for 24 hours. After that samples were left in the open air.

Figure 5: Sample after heat curing

3.10 Exposed to Atmosphere

After heat curing samples were kept in the open atmosphere for 3, 7, and 14 days. After that samples were tested for compressive strength at 3, 7 and 14days.

4 RESULTS

4.1 X-ray fluorescence (XRF)

XRF was performed on the Wheat Straw Ash which was burned at 600 °C for 2 hours in Muffle furnace in order to obtain the chemical composition of the ash which is given in the table below. According to the standard ASTM C618, in order for a material to be classified as a pozzolana its (SiO_2 + Al_2O_3 + Fe_2O_3) should be equal to or greater than 70%.

Table 3: XRF test results

Chemical Compounds (%)	**WSA at 600 °C**
SiO_2	77.4
K_2O	5.4
Al_2O_3	1.5
Fe_2O_3	1.3
CaO	3.9
MgO	1.9
TiO_2	0.97
LOI	5.6
(SiO_2 + Al_2O_3 + Fe_2O_3)	80.2

4.2 Compressive Strength Test

The compressive strength results of the one-part geopolymer mortar samples at 3, 7, and 14 days are provided in Figures 6. The results reflected that the early age strength of a one-part geopolymer is greater and later on strength. It can be seen because a one-part geopolymer gains its maximum strength at 3 days after heat curing at 70 ºC in an oven. Moreover, the compressive strength of the samples formed by 80 % WSA and 20% Bentonite is higher than the samples formed by 90% WSA and 10% Bentonite, 30 % WSA, and 70 % bentonite because of the shrinkage cracks that were appeared on their surface. It was concluded that strength depends upon the percentage of activators that generate alkali base reactions in it and the initial heat curing after casting.

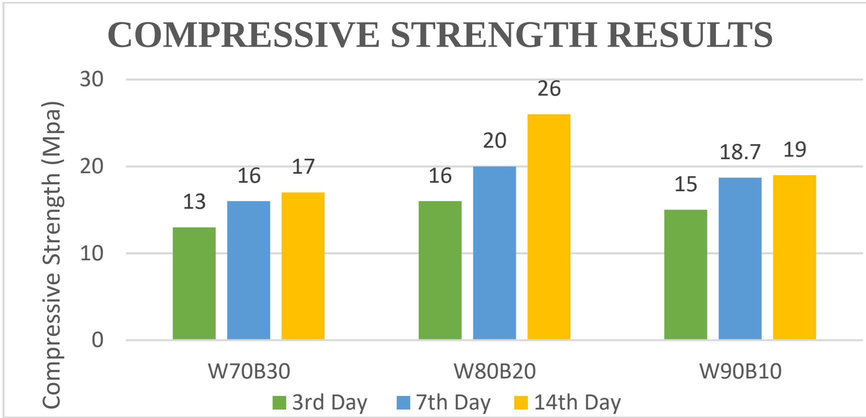


Figure 6: Compression strength results of mortar samples at 3rd, 7th and14th days.

5 CONCLUSION

Following conclusions can be drawn from the conducted study:

- The early age strength of a one-part geopolymer is greater than later strength.
- One-part geo-polymer gains its maximum strength at 3 days after heat curing at 70 ºC in an oven.
- Comparatively high compressive strength was of the samples formed by 80 % WSA and 20% Bentonite.
- Higher bentonite ratios cause shrinkage cracks that appeared on the surface.
- Strength depends upon the percentage of activators that generate alkali base reactions.

The above conclusions indicate that the One-Part Geopolymer Concrete can be used where early-stage strength is required because it gains its maximum strength in 3 days after heat curing in an oven. It also indicated that by using higher percentage ratios of either WSA or Bentonite reduces Strength.

PRACTICAL IMPLEMENTATION

The application of geopolymer is same as the cement concrete but leading the world towards sustainability geopolymer is preferred. Geopolymer concrete is used for construction of pavements, retaining walls, water tanks and precast bridge decks and in the structure which are prone to sulfate attack. Recently the four-story structural building for public use is constructed using geopolymer concrete by the University of Queensland's Global change Institute. Another example is the building of Toowoomba Well camp Airport in which Geopolymer concrete was used.

ACKNOWLEDGMENT

The authors would like to thank every person/department who helped thorough out the research work, particularly Engr. Dr. Muhammad Faisal Javed. His careful reviews and constructive suggestions are gratefully acknowledged.

REFERENCES

[1] Ali, N., Jaffar, A., Anwer, M., Khan, S., Anjum, M., Hussain, A., ... & Ming, X."The greenhouse gas emissions produced by cement production and its impact on environment: A review of global cement Processing". *International Journal of Research (IJR)*, vol. *2*(2), pp 1-13, 2015.

[2] Lee, Z. H., Sethupathi, S., Lee, K. T., Bhatia, S., & Mohamed, A. R. "An overview on global warming in Southeast Asia: CO2 emission status, efforts done, and barriers". *Renewable and Sustainable Energy Reviews*,vol. *28*, pp 71-81, 2013.

[3] Yasina, M., Bhuttob, A. W., Bazmia, A. A., & Karimb, S."Efficient utilization of rice-wheat straw to produce value–added composite products" *International Journal*, vol. *1*(2), pp 1-8, 2010.

[4] El-Sayed, T. A., Erfan, A. M., & Abd El-Naby, R. M. "Recycled rice & wheat straw ash as cement replacement materials". *Journal of Engineering Research and Reports*, vol. 5(2), pp 1-9, 2019.

[5] Brock, P., Madden, P., Schwenke, G., & Herridge, D."Greenhouse gas emissions profile for 1 tonne of wheat produced in Central Zone (East) New South Wales: a life cycle assessment approach". *Crop and Pasture Science*,vol. *63*(4), pp 319-329, 2012.

[6] Memon, S. A., Wahid, I., Khan, M. K., Tanoli, M. A., & Bimaganbetova, M. "Environmentally friendly utilization of wheat straw ash in cement-based composites". *Sustainability*, vol. *10*(5), pp, 1322, 2018.

[7] Akbar, J., Alam, B., Ashraf, M., Afzal, S., Ahmad, A., & Shahzada, K."Evaluating the Effect of Bentonite on Strength and Durability of High Performance Concrete". *Int. J. Adv. Struct. Geotech. Eng*, vol. *2*, pp 1-5, 2013.

[8] Ahmad, S., Barbhuiya, S. A., Elahi, A., & Iqbal, J."Effect of Pakistani bentonite on properties of mortar and concrete". *Clay Minerals*, vol. *46*(1), pp 85-92, 2011.

[9] Khan, M. S., Ali, F., & Zaib, M. A. "A Study of Properties of Wheat Straw Ash as a Partial Cement Replacement in the Production of Green Concrete". *University of Wah Journal of Science and Technology (UWJST)*, vol. *3*,pp 61-68, 2019.

[10] Mirza, J., Riaz, M., Naseer, A., Rehman, F., Khan, A. N., & Ali, Q."Pakistani bentonite in mortars and concrete as low cost construction material". *Applied Clay Science*,vol. *45*(4), pp 220-226, 2009.

DESIGN AND PROBABLE IMPROVEMENT OF FIBER-REINFORCED CONCRETE CANAL-LINING BY ROLE OF ROUGHNESS COEFFICIENT

[a] Haroon Imtiaz, [b] Talha Ahmed
a: Faryal Builders and Contractors, Islamabad, haroon.imtaiz98@.gmailcom
b: Department of Civil Engineering, Capital University of Science and Technology, engr.talhaahmed@outlook.com

Abstract- Flow resistance in channels carries prime importance for different purposes like evaluation of stage-discharge relationship. All relationships among Manning's Roughness Coefficient (N) and Froude Number (Fr) result in obtaining valuable information concerning design of an economical section, implementation and reducing the cost of construction. Fiber Reinforced Concrete (FRC) is strongly gaining attention of researchers which is credited to its improved properties. The necessity for optimal design of water-conveyance structures offers a wide range of research in the field of Water Resource Engineering. A review carried-out on optimal channels design specifies that alteration of Manning's Roughness Coefficient (N) with water depth has not been considered. This study primarily focusses on this variation of roughness coefficient in design of lined canal with the fiber-reinforced composites. So, the substantial difference regarding the results achieved for both scenarios, roughness coefficient of FRC compared with the conventional roughness coefficients of materials validates the need for considering variation of (N) with water depth. Moreover, when dealing with a distinctive design problem by means of the proposed equation it indicated the adequacy and the need for considering variable roughness while designing an economical section.

Keywords- Alternative, Canal, Concrete-Lining, Fibers, Manning's Roughness Coefficient.

1 INTRODUCTION

Design of open channels is conducted for transporting water at atmospheric pressure and may well be constructed in many shapes. When water flows in an open channel, it must have a free surface which is subjected to atmospheric pressure. So, the flow conditions in an open channels are complex as the position of the free surface will probably change with respect to time and space, and also by the fact that the discharge, depth of flow and the slope of the free surfaces and of the channel bottom are independent [1]. Flow resistance in channels is of key importance for different purposes like evaluation of stage-discharge relationship, and the assessment of sediment transport from the hydraulic properties of the channel by utilizing transport formulas. All relationships among Manning's Roughness Coefficient (N) and Froude Number (Fr) result in obtaining valuable information concerning design of an economical section, implementation and reducing the cost of construction [2].

The cross-section having maximum velocity or minimum area is in general, considered for lined canals. Such section is supremely effective (based on economy) as it includes least amount of earthwork. Design of irrigation canals for uniform flow includes optimization of cost by minimizing the flow perimeter and flow area to a minimum. Moreover, assessing the velocity and depth of flow are substantial for selecting adequate lining material. Special liners which do not get affected by erosion (such as concrete) are used where high velocity is permitted. For designing an economical section, the Manning's equation is most widely accepted as adequate design equation [3]. Seepage and erosion to the bottom of channel and banks can be controlled by irrigation lining. Moreover, as the roughness is reduced in lined channels hence it permits channels to transport greater flow as compared to larger un-lined channels. This efficiency means that channel can be constructed in less land. In hydraulics engineering, to design water structures, frictional coefficient (f) serves as the critical parameter while velocity, discharge and flow profile calculation plays a vital role in flood management, water resource projects and the determination of hydraulic effects for river conservation [4]. Moreover, broad knowledge of the resistance characteristics of alluvial streams is of great importance when studying different applications of water resources. The contribution of the factors like silting, scouring, location of bridges, flood forecasting, prediction of aggradation and degradation due to the presence of hydraulic structures and so on are key contributor in design of canals [5].

The aim of this research is to investigate the effect of fibre reinforced concrete lining in Manning's roughness coefficient on Froude number in open channel and resistance to flow through channel. In recent years, various researchers have been conducted regarding the roughness coefficient using Manning's equation. However, there are still uncertainties remaining regarding the precise value and effect of roughness coefficient by using fiber-reinforced concrete on discharge in channels. Moreover, to develop relationship between different parameters, especially Froude number with Manning roughness coefficient (N), and other factors velocity (V) and head (H), is considered in order to find useful relations.

2 SIGNIFICANCE OF THE STUDY

Roughness coefficient is widely adopted by the Manning's equation for lined-canal sections. The discharge of canal-sections are dependent on channel slope and roughness coefficient. Significantly, the design slope and depth of flow for channel can be increased in accordance with the roughness coefficient to achieve non-silting and non-scouring channels. Engineers should adopt the viable parameters of FRC in design for the improved characteristics of hydraulic structures.

3 LINED CANAL DESIGN PARAMETERS

The Manning Equation is the most commonly used equation to analyze open channel flows. The Manning Equation is utilized in lined canal channel designs calculation as in (1) and (2).

$$Q = A\ x\ V \qquad (1)$$

$$Q = \frac{A}{n} \times R^{\frac{2}{3}} \times S^{\frac{1}{2}} \qquad (2)$$

The Manning Equation was developed for prismatic channels. Prismatic channels have constant dimensions along its length including depth with the steady state of flow.

3.1 *Design Cross-Section*

The equation (2) is stated in terms of flow, as flow area (A) is multiplied on both sides of the equation. In (2), left hand side can be stated as A*V as it is equivalent to flow (Q) in the continuity equation. Moreover, this equation can be effectively utilized to assess the velocity (V) by eradicating the area (A).

3.2 *Hydraulic Radius*

The hydraulic radius (R) is the ratio of cross-sectional area to wetted perimeter. It is one of the most important property of a channel as it controls the discharge of water. Moreover, hydraulic radius and volume of water that a channel can carry are directly related i.e. a river having greater (R) will have greater flow velocity, and it will also have greater cross-sectional area through which water can travel quickly. Also, it accounts for geometry of the channel.

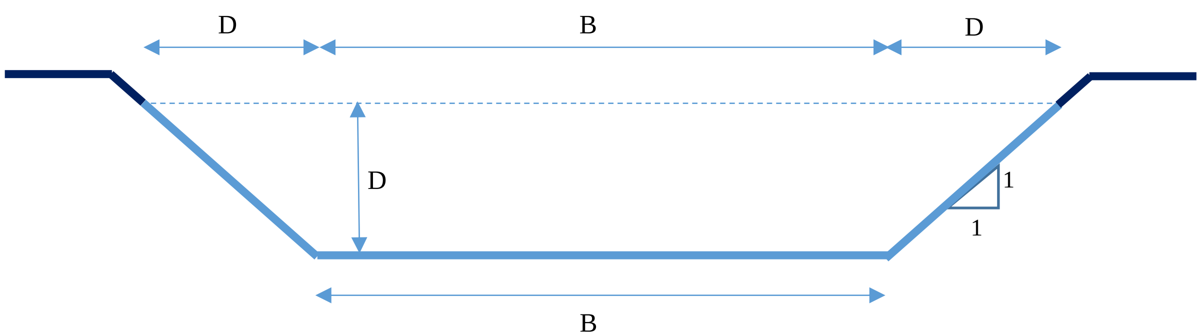


Figure 1: Schematic diagram of canal section for design

3.3 Slope of energy gradient

Generally, energy gradient slope is utilized, which signifies that due to friction, energy is released at a certain rate from the conduit. This form of equation permits it to be utilized in order to carry-out an analysis on conduits that do not only flow under uniform conditions but also flows under different conditions.

3.4 Roughness coefficient (Manning's Coefficient)

The Manning's coefficient (N) is a unit less quantity which signifies the frictional factor (*f*) or the roughness of the conduit. Moreover, (N) is higher in case of rougher conduits having high friction whereas (N) is lower in case of smoother conduits having less friction. Manning's coefficient (N) is an empirically derived coefficient and depends upon various factors including sinuosity and surface roughness.

4 ROLE OF ROUGHNESS COEFFICIENT

Flow resistance explicates the influence of friction on flow due to channel characteristics. Also, roughness equation is used for its estimation. Moreover, resistance coefficient can be stated as magnitude of resistance. In an open channel, the study of flow resistance is a delicate concept and there is no ideal approach to assess it (Järvelä, 1998). The factors that affect the flow resistance to a great extent are described below and it shall be observed that all of these factors are interdependent to a certain extent (Chow, 1959, 1973; French, 1986; and Bin Abrahim, 2011). Among the top of the factors surface roughness is indicated by the size and shape of the roughness particles of the material forming the wetted perimeter and producing the effect of retardness on flow. Retarding effect is greatly influenced by the bottom irregularities including the material roughness. Vegetation evidently decreases the capacity of flow for the channel and hinders the movement of flow. This effect depends primarily on stiffness, height, density, spreading and type of vegetation. Seasonal change influences the growth of weeds, willow and trees, aquatic plants and grass on the banks of channel or within the channel. On the other hand, channel shape, size and irregularity principally refers to shape dissimilarities in the channel, X-section and wetted perimeter along the gradient and slope of the channel. Erosion and sedimentation can alter the flow movement either to move un regular form or to divert and make irregular form. The factors mainly depend upon roughness characteristics and soil material type. Obstructions, for instance, debris flows, fallen trees, bridges, log jams and stones can have a noteworthy influence on the flow resistance. Stage-Discharge generally effect flow resistance in such a way that when stage-discharge increases, it leads to decrease in roughness coefficient.

5 PROBABLE IMPROVEMENT IN DESIGN

Concrete linings carry number of benefits and are used widely despite of their relatively higher cost. Cement concrete lining made from selected aggregate provides very satisfactory service. Cement concrete linings are optimal for main canals that carry a greater flow at high velocities. The conveyance of the channel is increased by smooth surface of the concrete lining.

Table 1- Roughness coefficient of different materials [20]

Sr. No.	Type	Material/ Type	Coefficient
1	Paved	Watertight roofs	0.70-0.85
2		Asphaltic cement streets	0.85-0.95
3		Portland cement streets	0.80-0.95
4		Paved driveways and walks	0.75-0.85
5		Gravel driveways and walks	0.15-0.30
6	Clayey soil lawns	2% slope	0.05-0.10
7		2-7% slope	0.10-0.15
8		>7% slope	0.15-0.20
9	Sandy soil lawns	2% slope	0.13-0.17
10		2-7% slope	0.18-0.32
11		>7% slope	0.25-0.35

Channel banks are kept at self-supporting slope 1.5H: 1V to 1.25 H : 1V, so that as a result lining is not needed to bear earth pressures and its thickness do not increase. They are durable, tough, hydraulic efficient and relatively impermeable

(Pencol, 1983). Lined irrigation canals serve for many purposes, out of which some are to minimize seepage, stabilize channel bed and channel banks, avoid piping through and under channel banks, reduce hydraulic roughness (flow resistance), promote movement rather than deposition of sediments, evade water logging of adjacent land, regulate weeds growth, lessen maintenance costs, assists cleaning and decrease movement of polluted groundwater plumes (Özcan, A., (2005).

There are a number of reasons to make relationship like this because channel irregularity includes irregularities in wetted perimeter and disparity in cross-section, shape, size along the length of channel and ripples, meandering, which leads to small pitches or grooves unsettled in the bottom of the channel. These irregularities certainly provoke roughness in addition to that caused by the surface roughness and other factors (Abdul Ameer, 1989). Also, vegetation can be look upon as a kind of surface roughness, and evidently decreases the channel capacity and impedes the flow. Ebrahimi et al., (2008) discovered direct relation between (N) and vegetation density which means increase in (N) results in an increase in vegetation density [22]. Likewise, the erosion of particles and presence of sediments effects the Manning's roughness coefficient.

Contrarily, silting can vary an irregular channel into a relatively uniform channel and reduce Manning's roughness coefficient (N), whereas scouring may result in an increase in (N) (Al Jawad, 1994). Side slope of the banks triggered an excessive effect on velocity, and plant growth also led to acquire the different values for (N). In lined irrigation canal, decrease in flow depth will result in decrease in velocity, Froude Number and increase in (N) [21].

Thus, from all those influencing parameters, the multi-regression analysis does not give a good understanding for the relation between (N) and stage-discharge and needs more detailed study for the concrete irrigation canals. The roughness coefficients of few materials are obtained empirically after the research work are presented in Table 1.

6 Conclusion

Based on the literature-based experiments which was investigated by many researchers in experimental tests on open channel, a summarized form of the findings and conclusions drawn from the studies are as follows:

- The relation between Froude number and Manning's roughness coefficient n in subcritical flow was appeared inverse relation having a good agreement with the observed value.
- The relation between Froude number and Manning's n in concrete lining irrigation canal is inverse relation with polynomial of fourth degree and showed moderate relation.
- The relationships between Fr and n in the natural are inverse relations. The causes of the inverse relation are due to the presence of many variables belong to the hydraulic conditions, and river morphology which affecting the measurements and relationships.
- The use of fibres provide the roughness which can be incorporated by increasing the depth of flow.
- The roughness coefficient is material characteristics, properties and roughness of each fiber varies and the design parameter of the canal design will be varied accordingly.

On the other hand, role of roughness coefficient plays a vital role in design of the non-silting and non-scouring channels, by the use of the fiber in concrete canal lining we can increase the depth of flow, by reducing the effective surface area which is more likely to reduce the losses as well. The use of fibres in canal lining can be more cost effective and more sustainable material leading to green infrastructures.

Acknowledgment

The author would like to give special thanks to Prof. Dr. Majid Ali for his kind support and acknowledge the organization and persons, especially who helped throughout this study. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] French, R.H. (2004). Hydraulic Design Handbook. USA: McGraw-Hill Book Co., 720

[2] Khatua, K.K., Patra, K.C. and Harish, S.B.T. (2007). Roughness characteristics in two stage meandering and straight compound channels, M. Engineering College, Mullana, Ambala, published in the Conference Proceeding on CEAC, Vol.9, pp. 1–11.

[3] Spieb, L., Teichert, G., Schwarzer, R., Behnken, H., Genzel, C., 2009. Moderne R€ ontgenbeugung, second ed. Teubner Verlag, Wiesbaden.

[4] Andharia, B.R. and Samtani, B.K. (2011a). Mathematical model based on mobility index for the prediction of flow resistance. International Journal of Advanced Engineering Sciences and Technologies 4(2):36–41

[5] Al Adili, A. (2016). Investigation of the Effect of Manning Roughness on Froude Number in Subcritical Flow. Journal of Construction and Building Materials, 1(1).

[6] Swamee, P. K. (1995). Optimal irrigation canal sections. Journal of Irrigation and Drainage Engineering, 121(6), 467-469.

[6] Niazkar, M., Rakhshandehroo, G. R., & Afzali, S. H. (2018). Deriving explicit equations for optimum design of a circular channel incorporating a variable roughness. Iranian Journal of Science and Technology, Transactions of Civil Engineering, 42(2), 133-142.

[7] Di Prisco, M., Plizzari, G., & Vandewalle, L. (2009). Fibre reinforced concrete: new design perspectives. *Materials and structures*, 42(9), 1261-1281.

[8] Niazkar M, Afzali SH (2015a) Optimum design of lined channel sections. Water Resour Manag 29(6):1921–1932

[9] Andharia, B. R., and Samtani, B. K. (2011a): Mathematical model based on mobility index for the prediction of flow resistance, Inter National Journal of Advanced Engineering Sciences and Technologies (IJAEST),Vol.4,No.2, pp. 36-41.

[10] Ebrahimi, N. G, Moghadam, M. F, Kashefipour, S. M, and Ebrahimi. K, (2008): Effects of flow and vegetation states on river roughness coefficients, Journal of Applied Sciences, Iran, Vol.8, No.11, pp. 2118-2123.

[11] I Abd-elmagied, M. F., & Abd-elhaleem, F. S. (2019). Design Aspects of Proposed Alternative Solutions for Tertiary Irrigation Canal. European Journal of Engineering Research and Science, 4(5), 139-147.

[12] Liu, W., Mohanty, A. K., Drzal, L. T., Askel, P., & Misra, M. (2004). Effects of alkali treatment on the structure, morphology and thermal properties of native grass fibers as reinforcements for polymer matrix composites. *Material Science and Engineering* 39(3), 1051-1054.

[13] Hosur, M., Maroju, H., & Jeelani, S. (2015). Comparison of effects of alkali treatment on flax fibre reinforced polyester and polyester-biopolymer blend resins. *Polymers and Polymer Composites*, 23(4), 229-242.

[14] Punyamurthy, R., Sampathkumar, D., Srinivasa, C. V., & Bennehalli, B. (2012). Effect of alkali treatment on water absorption of single cellulosic abaca fiber. *BioResources*, 7(3), 3515-3524.

[15] Ali, M., Liu, A., Sou, H., & Chouw, N. (2012). Mechanical and dynamic properties of coconut fibre reinforced concrete. *Construction and Building Materials*, 30, 814-825.

[16] Peled A, Bentur A. Geometrical characteristics and efficiency of textile fabrics for reinforcing cement composites. Cem Concr Res 2000;30(1):781–90

[17] Chandar, S. P. and Balaji, C. J. (2015). Experimental study on the mechanical properties of concrete mixed with jute fiber and steel fiber. International Research Journal of Engineering and Technology, 1(2),77-82

[18] Cui, J. H., Xie, Z. Q., & Xiao, H. J. (2013). Cause analysis on the cracks in concrete plate of canal lining. Applied Mechanics and Materials, 405, 2596-2599

[19] Kraatz, D. B. (1980). Irrigation Canal Lining. China Water Power Press, China.

[19] Morgado, F., Lopes, G. J., de Brito, J., & Feiteira, J. (2012). Portuguese irrigation canals: lining solutions, anomalies, and rehabilitation. Journal of performance of constructed facilities, 26(4), 507-515.

[20] Salah Abd Elmoaty, M., & TA, E. S. (2020). Manning roughness coefficient in vegetated open channels. Water Science, 34(1), 121-128.

[21] Hydraulic roughness of grassed open channel (A laboratory study), project in Civil Engineering.

[22] Fathi-Moghadam, M., Kashefipour, M., Ebrahimi, N., & Emamgholizadeh, S. (2011). Physical and numerical modeling of submerged vegetation roughness in rivers and flood plains. Journal of Hydrologic Engineering, 16(11), 858-864.

UTILIZATION OF WASTE PLASTICS AGGREGATE IN CONCRETE: A REVIEW

[a] Safeer Ullah
a: Department of Civil Engineering, CUI, Abbottabad Campus.safeer@cuiatd.edu.pk

Abstract- Plastic a material of thousand uses is enormously produced worldwide, this production has significantly increased the generation rate of plastic waste which is causing a serious threat to life on earth and environment. Recycling and reuse of plastic waste incorporated in concrete as aggregate is an eco-friendly solution, as it decreases the incineration and safeguarding the valuable land from landfilling. It has drawn attention many researchers and in the last decades extensive studies have been done and published on the replacement of plastic waste aggregate in concrete. This paper aims at the review of the latest research on concrete made with plastic aggregate. Discussions are made on the making of aggregate from plastic waste, followed by physical properties, mechanical properties and durability performance of plastic waste concrete. Due to lesser specific gravity of plastic, decrease in dry density is concluded. The Reduction in Compressive is attributed to the weaker bond of plastic waste aggregate with mix. Lessons learned for the practical applications and recommendations for future study are provided.

Keywords- Aggregate, Concrete, Mechanical Properties, Plastic Waste.

1 INTRODUCTION

Plastic can be referred as a material of thousand uses, it meets demand in almost everything from automotive to food industries, electronics, clothing, packaging and medical equipment's. associated with its usage, worldwide, plastic is enormously produced. Materials that are produced in access in the production units than its elimination on earth, result in the environmental issues [1]. The excessive production of polymeric materials, and their globally accepted and versatile use, associated with the acceptance they have gained, make these materials devastatingly hazardous to our lives on Earth and all the habitants of it [2]. As delineated by United Nations Environment Program (UNEP), the worldwide generation was more than almost 400 Million tons of plastics annually. Figure 1 presents the plastic wastes production and generation from 1950s to 2015, throughout the world [3]. After the usage, the unwanted plastic is now categorized as waste and a huge amount of landfill is needed for the disposal as that much plastic cannot be recycled in plant a single day [4]. Each year, plastics waste of nearly 30 million metric tons (Mt) of the overall municipal solid waste (MSW) generation of United States only, and less than 9% is taken to recycling. Although recycling practices are performing well but the defective tractability of municipal consumer is causing the low figure of Recycling. Some of scientific limitations are the stupendous hinderance to plastics recycling [5]. It has been estimated that globally around 8000 Mt as of freshly produced plastics to date. Up till 2015, approximately 6200 Mt of waste polymeric materials had generated, around 9%of which had been put for recycling, 12% was incinerated or used for energy production, and 79% disposed in environment which is finally disturbing the aquatic as well. If current production, higher generation rate continue, by 2050 approximately 12,500 Mt of plastics will overburden the natural environment [6]. Traditionally, plastics are very tough and not readily biodegradable in the surroundings exposed to environmental effects. Thus, plastics waste can remain on land for longer durations or may be many decades. Due to its high non bio degradability factors and chemically un reactive nature, Polymeric waste needs many of years for elimination in normal environmental conditions [7]. Currently plastics are derived from energy resources, about 4% of the resources are used for production of plastic and similar amount is provided as a raw materials [8].

Inequalities in existing plastic control methods and regulations are particularly pronounced in developing countries with high plastic waste generation [9]. The presence of large quantities of wasted plastic and the low biodegradability due to polymeric chains, adversely affect the environment. All types of plastic used in everyday life eventually become waste and cannot be recycled quickly, and tons of plastic waste requires large areas of land to be disposed of [4]. Waste recycling is important in different sectors; it helps to recycle, reduces energy production and pollution and services in the production and use of renewable natural resources [10]. The generation and recovery rate of plastic waste in Municipality solid waste (MSW) of USA, from 1960 to 2012 are shown in Table 1 [11]. The amount of plastics waste generated in USA MSW increased from around 0.4 million tons to 31.70 million tons in the last 50 years. The generation of plastic waste increased approximately 80 times that in 1960s. ironically, the efficient recovery and recycling was not started until 1980, when started, its rate was 0.3% that year. Apart from this technological development and awareness in the span of three and half decades, the recycling rate jumped to around 9% in 2012 [12].

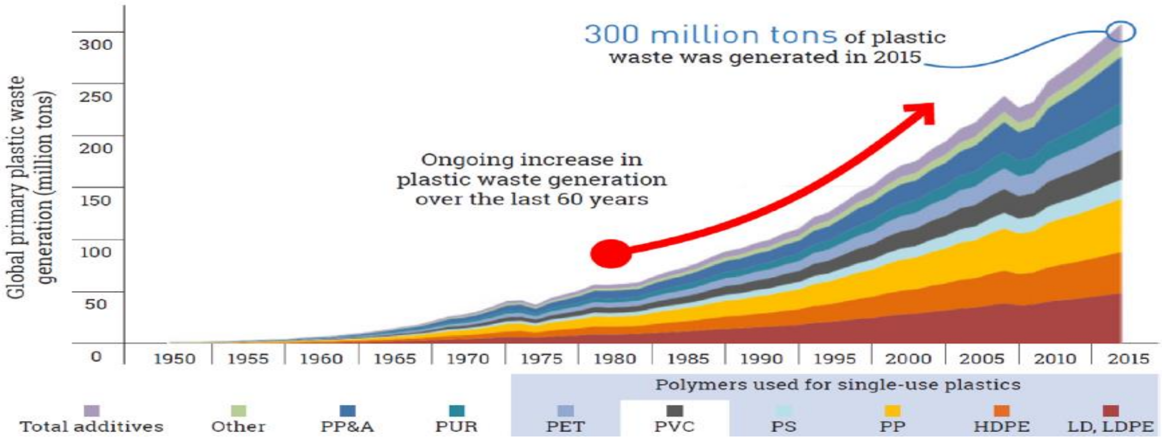


Figure 6: Global primary plastic waste generation in million tons according to UNEP report[3]

Waste reuse is significant in from various applications of plastic recycling, minimize energy production and environmental hazards and provide help in safeguarding natural resources which can last for a longer time[13]. Landfilling is now considered the last resort in dealing with plastic waste because it requires a huge amount of space and causes long-term pollution problems. By this method, recycled plastics can be reused without degradation in quality during the service cycle, and more importantly, the recycled plastics substitute the use of virgin construction materials [14]. Plastic waste aggregate replacement has been extensively investigated by researcher especially in last decades. The aim of this paper is to review the latest research on plastic aggregate replacement in concrete. In this study physical and mechanical properties and durability performance of concrete with plastic aggregate are discussed. Furthermore, recommendations for future studies in this field are provided.

Table 6: Generation, recovery and recovery rate of plastic waste in United States MSW from 1960 to 2012 [11].

Year	1960	1970	1980	1990	2000	2005	2008	2010	2012
Generated(1000t)	391	2900	6830	17130	25550	29380	30260	31290	31750
Recovery (1000t)	Neg	Neg	20	370	1480	1780	2140	2500	2800
Recovery rate	Neg	Neg	0.30%	2.20%	5.80%	6.10%	7.10%	8.00%	8.80%

2 MAKING OF AGGREGATE FROM PLASTIC WASTE

Various types of plastic wastes are being used in concrete as aggregate replacement, but the main types are polypropylene (PP), PVC and PET [15]. These plastic could be processed and transformed in three set ups before they can be further utilized as plastic aggregate in concrete [8]. At first stage, various impurities like label of the product and adhesives should be cleaned and disinfected by washing with detergent. This is significant for making sure that finished product has consistent. The next stage is the shredding, where the plastic is teared up into small pieces or flakes. At last stage, the shredded pieces are melted and then pellet are made. This type of extrusion is simple and the oldest way of transformation process, usually adopted for PET. The latest development in processes of extrusions are molding and converting into extrusion foam[16]. Plastic aggregate has low specific gravity and bulk density than conventional aggregate, some related properties of different types plastic waste are shown in Table 2. The particles of plastic aggregates prepared, have impermeable and smooth surface compared to river sand, resultantly, a weaker bond is formed between waste aggregate and cement mix. therefore, to compensate the loss in mechanical properties caused by this weaker bond, usually pozzolan and plasticizer are used [17]. In addition, modern foaming technology and surface granulation technology which modify the exposed layer of plastic waste aggregate, can significantly enhance the overall mechanical behavior. Kou et all used superplasticizer and granulation of the waste aggregates for achieving improved mechanical properties [18].

Table 7: Bulk density and specific gravity of plastic waste aggregate

Plastic waste type	Bulk density(kg/m^3)	Specific gravity	Reference
PVC	641	1.3	[19]
PET	438	1.34	[20]
EPS	30	0.34	[21]
LDPE	179 ±12	0.92	[22]
PP	515	0.90	[21]

3 PROPERTIES OF CONCRETE MADE WITH PLASTIC WASTE AGGREGATE

3.1 *Physical properties*

a. *Slump*

A number of parameters such as water-binder ratio, shape and percentage replacement of the plastic waste results in different values of slump of plastic waste concrete [12]. The replacement of plastic waste influenced the amount free water in concrete and hence alter the workability.[4]. Rehmani et all postulated that that the workability of concrete made with PET waste of flaky shape was decreased due to the effect on free water of concrete. It was also noted that increase in plastic waste content effected workability more pronounced. The decrease in workability was more than 40% when plastic waste replacement was increased at different increment from 0 to 15%. [23]. Silva et all reported that workability decreases with increase in plastic size and roughness causing greater porosity that hindered workability [20]. Saikia and Brito concluded that shape of plastic waste effected the slump. Three different shapes of shredded fractions i.e. fine range, course range and heat-treated cylindrical pellets were used. A slight increase in slump was noted with incorporation of heat-treated cylindrical pellets. Replacement of fine range and course range shredded fraction resulted in sharply decreased values of slump [24]. Researchers have concluded that increase in percentage replacement of plastic waste, decreases the slump values as shown in Table 3.

Table 8: Slump value of different types of plastic waste aggregate concrete

SNO	Plastic waste type	Percentage level (%)	Slump value (mm)	Reference
1	Polypropylene	0	135	[20]
		7.5	131	
		15	130	
2	Polyethylene terephthalate	0	80	[23]
		5	65	
		10	49	
		15	33	
3	MSW Plastic waste	0	53	[39]
		5	49	
		10	37	
		15	29	

b. *Density/ unit weight*

It is postulated that fresh density and unit weight of concrete reduces with addition of plastic waste in concrete. Lima et al [25] concluded that replacement of waste ethylene acetate up to 50% in concrete reduced fresh wet, oven dried and dry densities by approximately 26% compared to control concrete. Colangelo et al [26] replaced polyolefins waste in concrete and compared the dry densities with control concrete. 35% plastic aggregate replacement resulted in 23% reduction in density. Similar results of reduction in density was presented by Islam et al [27].

3.2 Mechanical properties

a. Compressive strength

The non-hydrating and hydrophobic effect, shape size and replacement level of plastic waste played significant part in controlling the behaviour related to compressive strength. Increase in PET waste replacement, reduced compressive strength generally. This compressive strength reduction was attributed to honey-com formation and failure [28]. Coppola et al [29] concluded that smaller and granulated plastic waste aggregate can reduce the loss in compressive strength. Similarly yang et al [15] presented that self-consolidated concrete with replacement of short column plastic waste lesser that 20 % replacement can increase compressive strength due to smaller fraction of plastic waste which can fill up the concrete voids. To prevent large reduction in compression strength the amount of plastic aggregate replacement should be less than 20%. Apart from this, larger plastic aggregate badly effects the compressive strength as it increases smooth surface layer and hence a week bond. Plastic waste of lamellar shape which increase the surface area and demand of water lead to further weakened aggregate mix bond [20].

b. Tensile strength

Similar performance like compressive strength, split tensile strength reduction was reported by many researchers. Frigione concluded that tensile strength reduced in concrete containing plastic aggregates of shredded PET bottles [30]. Punitha et al investigated different content of plastic with 10% metakaolin in concrete and split tensile strength reduction was up to 40% and 36% at 7 and 28 days respectively [31]. Comparatively tensile strength was less affected by plastic size , however percent replacement and size of plastic waste effect was significant [24]. The Anova results postulated that temperature significantly affected the tensile strength, it was then followed by w/c ratio and type of plastic waste. at normal temperature, the addition of plastic waste particles decreased the tensile strength, while the Polypropylene fibres tend to maintain or enhance tensile strength. The results of the plastic waste in concretes exposed to temperature 600°C showed a positive effect on the tensile strength due to polymeric addition , with no difference for different w/c ratios [32].

c. Flexural strength

Sadrimozi et all reported that increasing replacement level of plastic waste, the concrete exhibited improved plasticity and flexibility making it less brittle in failure as the nature of plastic is more flexible compared to conventional concrete [33]. Ruiz-herrero reported the materials had low mechanical properties in term of flexural strength, though the plastic waste was not intended to be part of structural element. It is pertinent to mention that improved mechanical properties could e achieved easily with higher content of cement or admixtures [34]. Similarly, Muhammad et al investigated flexure strength variation in concrete made with partial replacement of poly vinyl chloride (PVC) aggregate. Experimental analysis showed that 15% PVC resulted an increase of 8% in flexural strength. In case of fine aggregate replacement, the flexure strength unaffected in the range of 30% to 65% replacement. However, reduction of 42% in flexure strength was found with 65% replacement of PVC as course aggregate [19].

3.3 Durability performance

a. Water absorption

Most researchers have reported that replacement level of plastic waste also caused an increment in porosity and hence higher water absorption of concrete. F. Colangelo investigated that substitution of 10%, 20% and 30% plastic waste increased open porosity by 19%, 31% and 40% while water absorption was increased was found to be approximately 9% to 15% accordingly [26]. whereas Iucolano et al [35] proposed that the increased porosity is attributed to difference in particle sizes and shape of plastic waste, and Brito et al [20] related this phenomenon to the weaker interfacial transition zone due smooth and impermeable surface of plastic waste aggregate. Apart from this the angulated plastic aggregate caused higher water absorption than corresponding regular and sphere-shaped aggregate. However finding obtained by Safi et al [36] were opposite to this.

b. Resistance to freeze and thaw

Wang and Meyer investigated the effect of freeze and thaw on impact polystyrene aggregate and expanded polystyrene foam in concrete. It was concluded that there was no effect of freeze and thaw resistance with replacement of high impact polystyrene in composites. However plastic aggregate in the form of expanded polystyrene foam improved the freeze and thaw resistance [37]. Ferrándiz and Alcocel concluded in their study that enhanced resistance was due to the performance of EPS to release the crystallization pressure of freezing water content which substantially reduces damage to composites.

However more strength reduction was examined when the substitution of EPS aggregate was higher than 50%, supposedly due poor workability [38].

4 LESSONS LEARNED FOR PRACTICAL APPLICATIONS OF PLASTIC WASTE

Concrete incorporated with plastic waste produce light weight concrete, studies shows that concrete of different plastic waste aggregate meet various criteria of various national parameters of lightweight concrete. Plastic waste concrete made with polypropylene increases the tensile strength and decreases the weight of the structure so it can be used for earthquake resistance structures. Increase in freeze and thaw resistance at higher percentage replacement make it suitable for use in extreme climatic conditions. Studies shows that many properties are improved with plastic waste incorporation, so a part associated with plastic waste disposal can be minimized.

5 CONCLUSION

Following conclusions can be drawn from the conducted study:

- Fresh and dry densities of concrete produced with plastic aggregate tend to decrease due to low specific gravity of polymeric materials.
- Reduction in Compressive strength was concluded by many researchers and it was attributed to the weaker bond of paste with plastic waste aggregate.
- At partial replacement of sand there was no effect on the freeze and thaw resistance however higher percentage replacement improved freeze and thaw resistance.
- Water absorption and porosity of plastic aggregate concrete is higher than conventional concrete however this flaw can be eliminated by incorporating rich cementitious paste.

Though an extensive research is available on plastic waste aggregate but a detailed study need to be done on leeching of toxic chemicals from plastic waste concrete and similarly a comprehensive research on the long term performance and recycling of plastic waste concrete is suggested to understand and verify its life cycle assessment.

ACKNOWLEDGMENT

The author would like to thank every person/department who helped thorough out the research work, particularly prof. Dr. Majid Ali for his kind and utmost sincere guidance in this study. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] M. Ilyas, W. Ahmad, H. Khan, S. Yousaf, K. Khan, and S. Nazir, "Plastic waste as a significant threat to environment - A systematic literature review," *Rev. Environ. Health*, vol. 33, no. 4, pp. 383–406, 2018, doi: 10.1515/reveh-2017-0035.

[2] M. Okan, H. M. Aydin, and M. Barsbay, "Current approaches to waste polymer utilization and minimization: a review," *J. Chem. Technol. Biotechnol.*, vol. 94, no. 1, pp. 8–21, 2019, doi: 10.1002/jctb.5778.

[3] U. UNEP, "Single-Use Plastics: A Roadmap for Sustainability," *Plásticos Un Solo Uso Una hoja ruta para la sostenibilidad*, 2018.

[4] R. Sharma and P. P. Bansal, "Use of different forms of waste plastic in concrete - A review," *J. Clean. Prod.*, vol. 112, pp. 473–482, 2016, doi: 10.1016/j.jclepro.2015.08.042.

[5] A. R. Rahimi and J. M. Garciá, "Chemical recycling of waste plastics for new materials production," *Nat. Rev. Chem.*, vol. 1, pp. 1–11, 2017, doi: 10.1038/s41570-017-0046.

[6] R. Geyer, J. R. Jambeck, and K. L. Law, "Production, use, and fate of all plastics ever made," *Sci. Adv.*, vol. 3, no. 7, pp. 25–29, 2017, doi: 10.1126/sciadv.1700782.

[7] N. Singh, D. Hui, R. Singh, I. P. S. Ahuja, L. Feo, and F. Fraternali, "Recycling of plastic solid waste: A state of art review and future applications," *Compos. Part B Eng.*, vol. 115, pp. 409–422, 2017, doi: 10.1016/j.compositesb.2016.09.013.

[8] J. Hopewell, R. Dvorak, and E. Kosior, "Plastics recycling: Challenges and opportunities," *Philos. Trans. R. Soc.*

B Biol. Sci., vol. 364, no. 1526, pp. 2115–2126, 2009, doi: 10.1098/rstb.2008.0311.
[9] K. P. Gopinath, V. M. Nagarajan, A. Krishnan, and R. Malolan, "Journal Pre-proof j. clean . prod," 2020.
[10] I. Ramli, H. Yaacob, N. A. Hassan, C. R. Ismail, and M. R. Hainin, "Fine aggregate angularity effects on rutting resistance of asphalt mixture," *J. Teknol. (Sciences Eng.*, vol. 65, no. 3, pp. 105–109, 2013, doi: 10.11113/jt.v65.2154.
[11] United States Environmental Protection Agency, "Definition of Solid Waste and Recycling," 2014, [Online]. Available: https://www.epa.gov/sites/production/files/2016-02/documents/soliddef.pdf.
[12] L. Gu and T. Ozbakkaloglu, "Use of recycled plastics in concrete: A critical review," *Waste Management*, vol. 51. pp. 19–42, 2016, doi: 10.1016/j.wasman.2016.03.005.
[13] I. Almeshal, B. A. Tayeh, R. Alyousef, H. Alabduljabbar, A. Mustafa Mohamed, and A. Alaskar, "Use of recycled plastic as fine aggregate in cementitious composites: A review," *Constr. Build. Mater.*, vol. 253, p. 119146, 2020, doi: 10.1016/j.conbuildmat.2020.119146.
[14] E. J. North and R. U. Halden, "Plastics and environmental health: The road ahead," *Rev. Environ. Health*, vol. 28, no. 1, pp. 1–8, 2013, doi: 10.1515/reveh-2012-0030.
[15] S. Yang, X. Yue, X. Liu, and Y. Tong, "Properties of self-compacting lightweight concrete containing recycled plastic particles," *Constr. Build. Mater.*, vol. 84, pp. 444–453, 2015, doi: 10.1016/j.conbuildmat.2015.03.038.
[16] F. Colangelo, R. Cioffi, B. Liguori, and F. Iucolano, "Recycled polyolefins waste as aggregates for lightweight concrete," *Composites Part B: Engineering*, vol. 106. pp. 234–241, 2016, doi: 10.1016/j.compositesb.2016.09.041.
[17] R. Madandoust, M. M. Ranjbar, and S. Yasin Mousavi, "An investigation on the fresh properties of self-compacted lightweight concrete containing expanded polystyrene," *Constr. Build. Mater.*, vol. 25, no. 9, pp. 3721–3731, 2011, doi: 10.1016/j.conbuildmat.2011.04.018.
[18] S. C. Kou, G. Lee, C. S. Poon, and W. L. Lai, "Properties of lightweight aggregate concrete prepared with PVC granules derived from scraped PVC pipes," *Waste Manag.*, vol. 29, no. 2, pp. 621–628, 2009, doi: 10.1016/j.wasman.2008.06.014.
[19] A. A. Mohammed, I. I. Mohammed, and S. A. Mohammed, "Some properties of concrete with plastic aggregate derived from shredded PVC sheets," *Constr. Build. Mater.*, vol. 201, pp. 232–245, 2019, doi: 10.1016/j.conbuildmat.2018.12.145.
[20] R. V. Silva, J. De Brito, and N. Saikia, "Influence of curing conditions on the durability-related performance of concrete made with selected plastic waste aggregates," *Cem. Concr. Compos.*, vol. 35, no. 1, pp. 23–31, 2013, doi: 10.1016/j.cemconcomp.2012.08.017.
[21] Y. Xu, L. Jiang, J. Xu, and Y. Li, "Mechanical properties of expanded polystyrene lightweight aggregate concrete and brick," *Constr. Build. Mater.*, vol. 27, no. 1, pp. 32–38, 2012, doi: 10.1016/j.conbuildmat.2011.08.030.
[22] A. Poonyakan, M. Rachakornkij, M. Wecharatana, and W. Smittakorn, "Potential use of plastic wastes for low thermal conductivity concrete," *Materials (Basel).*, vol. 11, no. 10, pp. 1–17, 2018, doi: 10.3390/ma11101938.
[23] E. Rahmani, M. Dehestani, M. H. A. Beygi, H. Allahyari, and I. M. Nikbin, "On the mechanical properties of concrete containing waste PET particles," *Constr. Build. Mater.*, vol. 47, pp. 1302–1308, 2013, doi: 10.1016/j.conbuildmat.2013.06.041.
[24] N. Saikia and J. De Brito, "Waste polyethylene terephthalate as an aggregate in concrete," *Mater. Res.*, vol. 16, no. 2, pp. 341–350, 2013, doi: 10.1590/S1516-14392013005000017.
[25] P. R. L. Lima, M. B. Leite, and E. Q. R. Santiago, "Recycled lightweight concrete made from footwear industry waste and CDW," *Waste Manag.*, vol. 30, no. 6, pp. 1107–1113, 2010, doi: 10.1016/j.wasman.2010.02.007.
[26] F. Colangelo, R. Cioffi, B. Liguori, and F. Iucolano, "Recycled polyolefins waste as aggregates for lightweight concrete," *Compos. Part B Eng.*, vol. 106, pp. 234–241, 2016, doi: 10.1016/j.compositesb.2016.09.041.
[27] M. J. Islam, M. S. Meherier, and A. K. M. R. Islam, "Effects of waste PET as coarse aggregate on the fresh and harden properties of concrete," *Constr. Build. Mater.*, vol. 125, pp. 946–951, 2016, doi: 10.1016/j.conbuildmat.2016.08.128.
[28] C. Albano, N. Camacho, M. Hernández, A. Matheus, and A. Gutiérrez, "Influence of content and particle size of waste pet bottles on concrete behavior at different w/c ratios," *Waste Manag.*, vol. 29, no. 10, pp. 2707–2716, 2009, doi: 10.1016/j.wasman.2009.05.007.
[29] B. Coppola, L. Courard, F. Michel, L. Incarnato, and L. Di Maio, "Investigation on the use of foamed plastic waste as natural aggregates replacement in lightweight mortar," *Compos. Part B Eng.*, vol. 99, pp. 75–83, 2016, doi: 10.1016/j.compositesb.2016.05.058.
[30] M. Frigione, "Recycling of PET bottles as fine aggregate in concrete," *Waste Manag.*, vol. 30, no. 6, pp. 1101–1106, 2010, doi: 10.1016/j.wasman.2010.01.030.
[31] V. Punitha, N. Sakthieswaran, and O. G. Babu, "Materials Today : Proceedings Experimental investigation of concrete incorporating HDPE plastic waste and metakaolin,", 2020.

[32] J. R. Camilo, A. B. Rohden, and M. R. Garcez, "Concrete with rejected recyclable plastic waste at high temperatures," *Mag. Concr. Res.*, pp. 1–1, 2020, doi: 10.1680/jmacr.19.00485.

[33] A. Sadrmomtazi, S. Dolati-Milehsara, O. Lotfi-Omran, and A. Sadeghi-Nik, "The combined effects of waste Polyethylene Terephthalate (PET) particles and pozzolanic materials on the properties of selfcompacting concrete," *J. Clean. Prod.*, vol. 112, pp. 2363–2373, 2016, doi: 10.1016/j.jclepro.2015.09.107.

[34] J. L. Ruiz-Herrero *et al.*, "Mechanical and thermal performance of concrete and mortar cellular materials containing plastic waste," *Construction and Building Materials*, vol. 104. pp. 298–310, 2016, doi: 10.1016/j.conbuildmat.2015.12.005.

[35] F. Iucolano, B. Liguori, D. Caputo, F. Colangelo, and R. Cioffi, "Recycled plastic aggregate in mortars composition: Effect on physical and mechanical properties," *Mater. Des.*, vol. 52, pp. 916–922, 2013, doi: 10.1016/j.matdes.2013.06.025.

[36] B. Safi, M. Saidi, D. Aboutaleb, and M. Maallem, "The use of plastic waste as fine aggregate in the self-compacting mortars: Effect on physical and mechanical properties," *Constr. Build. Mater.*, vol. 43, pp. 436–442, 2013, doi: 10.1016/j.conbuildmat.2013.02.049.

[37] R. Wang and C. Meyer, "Performance of cement mortar made with recycled high impact polystyrene," *Cem. Concr. Compos.*, vol. 34, no. 9, pp. 975–981, 2012, doi: 10.1016/j.cemconcomp.2012.06.014.

[38] V. Ferrándiz-Mas and E. García-Alcocel, "Durability of expanded polystyrene mortars," *Constr. Build. Mater.*, vol. 46, pp. 175–182, 2013, doi: 10.1016/j.conbuildmat.2013.04.029.

[39] M. M. Al-Tayeb, H. Ismail, O. Dawoud, S. R. Wafi, and I. Al Daoor, "Ultimate failure resistance of concrete with partial replacements of sand by waste plastic of vehicles under impact load," *Int. J. Sustain. Built Environ.*, vol. 6, no. 2, pp. 610–616, 2017, doi: 10.1016/j.ijsbe.2017.12.008

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

EXPERIMENTAL DETERMINATION OF THE MECHANICAL PROPERTIES OF BRICK MASONRY AND LOW STRENGTH CONCRETE BLOCK MASONRY

[a] Raheel Asghar, [b] Asif Shahzad, [c] Syed Uzair Amjad, [d] Ali Akhtar
a: Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus, raheelasghar68@gmail.com
b: Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus, shahzaasif@gmail.com
c: Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus, uzairshah197@gmail.com
d: Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus, aliakhtarglt@gmail.com

Abstract- A practice of constructing reinforced concrete frame structures with unreinforced masonries is being followed all over the world. In the past, these masonries were considered as the non-structural elements of the building, but recent researches have shown their importance during seismic events where they greatly enhance the performance of the building. The most common type of masonries used in Abbottabad are brick masonry and low strength concrete block masonry. These masonries are the composite materials that generally consist of individual units of the bricks or concrete blocks bonded together with the help of mortar. Mortar is also the mixture of cement, sand and water. Due to this heterogeneity in the composition, mechanical properties of infill masonries are not the same as that of the individual units. Moreover, there are variety of materials available in the construction market, a most widely adopted material in one region may not be used entirely in other regions e.g. low strength concrete blocks that are most widely used masonry material in Pakistan especially in Abbottabad but are not considered outside the Asian sub-continent. Therefore, it is desirable to find out the mechanical properties of these infill masonries experimentally at the local level in order to assess their response under different types of loading e.g. seismic loading. This research aims at the experimental determination of mechanical properties of two types of infill masonries i.e. brick masonry and low strength concrete block masonry. The research is further focused on the establishment of empirical relationships between different mechanical properties and making their comparison with those given by other researchers and international standards. For this purpose, masonry prisms for both these types of infill masonries were constructed and tested in the concrete laboratory of COMSATS University Islamabad, Abbottabad Campus and the results were reported in terms of compressive strength, elastic modulus, shear modulus, Poisson's ratio. From the outcomes of this research it was found out that compressive strength of masonry depends on the compressive strength of masonry units and number of joints in a square unit. Greater the compressive strength of masonry unit, greater will be the compressive strength of masonry whereas greater the number of joints in a square unit, lesser will be the compressive strength of masonry and vice versa. Moreover, compressive strength, elastic modulus, shear modulus and Poisson's ratio were found to be 790 psi, 410 ksi, 166 ksi and 0.2383 for brick masonry whereas 400 psi, 250 ksi, 97 ksi and 0.3127 in case of concrete block masonry respectively.

Keywords - Infill Masonries, Compressive Strength, Elastic Modulus, Shear Modulus, Poisson's Ratio.

1 INTRODUCTION

In the present time, a practice of constructing reinforced concrete frame structures with masonry infill walls is being followed all over the world [1]. In the past, these masonry infill walls were considered as the non-structural elements of the building [1], but recent researches have shown their importance during seismic events where they greatly enhance the performance of the building. The most common type of masonries used in Abbottabad are either the brick masonry or low strength concrete block masonry. These masonries are the composite materials that generally consist of individual units of the bricks or concrete blocks bonded together with the help of mortar. Mortar is also the mixture of cement, sand and water. Due to this heterogeneity in the composition, mechanical properties of the infill masonries (i.e. compressive strength, elastic modulus, Poisson's ratio etc.) are not the same as that of the individual units. Individuals units of brick or concrete block masonries usually carries greater compressive strength and modulus of elasticity as compared to their masonries. The mechanical properties of the infill masonries generally depend upon the mechanical properties of individual units, quality of the binding material being used in the joints and workmanship. Though different building design codes provides empirical relationships for the determination of these parameters, but the quality of the material and workmanship being the major influencing factors for these parameters do not remain same in all parts of the world. Moreover, there are variety of material available in the construction market, a most widely adopted material in one region may not be used entirely in other regions e.g. low strength concrete blocks that are most widely used masonry material in Pakistan especially in Abbottabad but are not considered outside the Asian sub-continent. Therefore, it is desirable to find out the mechanical properties of these masonries experimentally at the local level in order to assess their response under different types of loading e.g. seismic loading.

Similar works have already been done on the determination of mechanical properties of infill masonries in different parts of the world. Saroj Phajju and Prachand Man Pradhan [2] have conducted an experimental research on the determination of mechanical properties of brick masonry. The results of this research yielded a value of 2.5 MPa, 2703.2 MPa, 915.1 MPa and 0.32 for compressive strength, shear strength, elastic modulus, shear modulus and Poisson's ratio of given masonry respectively. Another researcher T.C. Nowofor [3] as a result of his experimental work have found out a value of 11.86 MPa, 7420 MPa and 0.33 for compressive strength, elastic modulus and Poisson's ratio of brick masonry respectively. Zeljke Radovanovic et. al. [4] on the basis of his experimental findings suggested a value of 2.89 MPa and 3190 MPa for compressive strength and elastic modulus of clay block masonry whereas 2.9 MPa and 6600 MPa for compressive strength and elastic modulus of concrete block masonry respectively. Another research made by Mohamad Gihad et. al. [5] found out the compressive strength and elastic modulus of concrete block masonry to be 10.56 MPa and 10145 MPa respectively. In another research made by Sayari Arash [6], compressive strength and elastic modulus of brick masonry were found out to be 3.7 MPa and 3751.3 MPa respectively.

This research aims at the experimental determination of mechanical properties of two types of infill masonries i.e. brick masonry and low strength concrete block masonry. The research is further aimed at the establishment of empirical relationships between different mechanical properties and making their comparison with those given by other researchers and international standards.

2 RESEARCH METHODOLOGY

Two different types of infill masonries (i.e. brick masonry and low strength concrete block masonry) were considered in the research for the investigation of mechanical properties i.e. compressive strength (f'_m), elastic modulus (E_m), shear modulus (G_m) and Poisson's ratio (ν). In order to do so, masonry prisms for both these wall types were constructed in the concrete laboratory of Comsats University Islamabad (CUI), Abbottabad Campus. These masonry prisms were then given proper curing for 28 days after which they were tested in universal testing machine (UTM) for compressive strength test. During the compression strength test along with the axial deformation, lateral deformation was also observed in order to determine Poisson's ratio. Due to the inability of testing device shear test was not conducted on the masonry prisms. Therefore, shear modulus was determined by using an empirical relationship as given in (1). Although this equation was derived assuming the material to be isotropic, but it can give reasonable results for masonry material as well. Most of building design programmers like ETABS and SAP 2000 use the same relationship for the determination shear modulus from elastic modulus and Poisson's ratio.

$$G_m = \frac{E_m}{2(1+\nu)} \tag{1}$$

2.1 Construction of Masonry Prisms

A total number of 3 masonry prisms for both these types of infill masonries were constructed on a relatively flat or levelled surface. These prisms were constructed with height to thickness ratio of 2 in case of brick masonry and 2.7 for concrete block masonry. The construction of these prisms was undertaken as per the standard procedure of ASTM C1314 [7].

Table 9: Physical Characteristics of Masonry Prisms

Prism Type	Length	Width	Height	Top Area
	(in)	(in)	(in)	(in^2)
Bricks Masonry	18	9	18	162
Concrete Block Masonry	18	6	16	108

2.2 Curing of Masonry Prisms

All the masonry prisms were kept at a normal room temperature of 24 ± 8 °C in moisture tight bags after the initial normal curing of 48 hours. The prisms were extracted from these bags two days before the test. The guidelines of ASTM C1314 [7] for the curing of masonry prisms were followed in their full spirit.

2.3 Testing of Masonry Prisms

All the masonry prisms were tested in accordance with the standard procedure of ASTM C1314 [7], and the results were reported in the form of compressive strength, elastic modulus, shear modulus and Poisson's ratio. Compressive strength was obtained as a maximum axial stress taken by the prism before undergoing failure whereas elastic modulus was obtained as the slope initial elastic region of stress strain curve. Moreover, during the compressive strength test a dial gauge was also installed at one side of the prism to observe its lateral strain. The results obtained were then plotted in the form of lateral vs longitudinal strain curve. The slope of linear curve between lateral and longitudinal strain gives the Poisson's ratio for the prism. Shear modulus was determined using (1).

Figure 7: Testing of Masonry Prisms

2.4 Testing of Masonry Units

For the sake of making comparison between compressive strength of masonry (f'_m) and masonry units (f'_{mu}), compressive strength test was also conducted on masonry units. For this purpose, 3 samples of both bricks and mortar were prepared. Mortar samples were prepared in the form of 2-inch cubes with cement to sand ratio of 1:3 whereas brick samples were prepared by filling the frog of Class-A bricks with mortar. After the preparation of test samples, compressive strength test was conducted in compression testing machine (CTM) in the concrete laboratory of Comsats University Islamabad, Abbottabad Campus. This test was conducted in accordance with the standard guidelines of relevant standards.

3 RESULTS

At the end of specified curing period of 28 days, all the masonry prisms were tested for compression test in UTM whereas masonry units in CTM. All the results obtained from the compression test were reported to the nearest 10 psi for compressive strength and 1000 psi for elastic and shear modulus. The Poisson's ratio was reported to the four decimal places. A more detailed description of average test results is given in table 2 and table 3. On the basis of test results, a comparison was made between different mechanical properties of masonry and masonry units. Analyzing the results, compressive strength of masonry was found to be some fraction of masonry unit. This loss of strength is due to the presence of weaker mortar and interface elements in the joints. Greater the number of joints, greater will be the loss of strength which can be observed from the test results of brick masonry prism where greater loss of strength was seen due to the greater number of joints. Compressive strength of mortar used in the joints was found to be 1720 psi. In table 2 and 3, the symbol f'_{mu} refers to the compressive strength of major masonry unit i.e. either bricks or concrete blocks.

Table 10: Average Test Results for Brick Masonry Prisms

Parameters	Values	Parameters	Relationship/Values
	(psi)		
f'_m	790	ν	0.2383
f'_{mu}	1880	$f'_m - f'_{mu}$	$f'_m = 0.4202 * f'_{mu}$
E_m	410000	$E_m - f'_m$	$E_m = 520 * f'_m$
G_m	166000	$G_m - E_m$	$G_m = 0.405 * E_m$

Table 11: Average Test Results for Concrete Block Masonry

Parameters	Values	Parameters	Relationship/Values
	(psi)		
f'_m	400	ν	0.3127
f'_{mu}	820	$f'_m - f'_{mu}$	$f'_m = 0.4878 * f'_{mu}$
E_m	250000	$E_m - f'_m$	$E_m = 625 * f'_m$
G_m	97000	$G_m - E_m$	$G_m = 0.388 * E_m$

A comparison between mechanical properties of masonry infill walls determined experimentally during this research is made with that of previous researches in table 4. From the comparison it can be seen that Nowofor [3] has overestimated the mechanical properties of infill masonry whereas Randovanovic [4] has underestimated the results among all. The mechanical properties determined by all other researches lie in between that of Nowofor [3] and Randovanovic [4]. It was also observed that mechanical properties determined during this research neither lies very close to someone else's nor deviates too much from any other presented. A comparison between empirical relationships proposed by each of the researcher is also made in table 5. From the comparison it can be observed that empirical relationship of mechanical properties of infill masonries proposed by this research comply with most of the other researches. The relationship between compressive strength and elastic modulus lies closer to that recommended by FEMA 356 [8] whereas relationship of compressive strength of masonry and masonry unit lies closer to that proposed by Nowofor [3]. The relationship among elastic and shear modulus is almost the same as proposed by all the researcher. Poisson's ratio was slightly overestimated by Phajju [2] and Nowofor [3] as compared to that presented in this research.

Table 12: Comparison of Mechanical Properties of Masonry

Research	Masonry Type	f'_m	E_m	G_m	ν
		(psi)	(ksi)	(ksi)	
This Research	Brick Masonry	790	410	166	0.2383
	Conc. Block Masonry	400	250	97	0.3127
Phajju [2]	Brick Masonry	360	392	133	0.32
Nowofor [3]	Brick Masonry	1720	1076	404	0.33
Radovanovic [4]	Clay Block Masonry	420	463	-	-
	Conc. Block Masonry	421	957	-	-
Gihad [5]	Conc. Block Masonry	1530	1471	-	-
Arash [6]	Brick Masonry	540	544	-	-

Table 13: Comparison of Empirical Relationships Between Different Mechanical Properties

Research	Masonry Type	f'_m - f'_{mu}	E_m - f'_m	G_m - E_m
This Research	Brick Masonry	42.02%	$E_m = 520 * f'_m$	40.5%
	Conc. Block Masonry	48.78%	$E_m = 625 * f'_m$	38.8%
Phajju [2]	Brick Masonry	22.5%	$E_m = 1085 * f'_m$	34%
Nowofor [3]	Brick Masonry	51%	$E_m = 626 * f'_m$	37.6%
Radovanovic [4]	Clay Block Masonry	44%	$E_m = 1104 * f'_m$	-
	Conc. Block Masonry	89%	$E_m = 2276 * f'_m$	-
Gihad [5]	Conc. Block Masonry	58%	$E_m = 961 * f'_m$	-
Arash [6]	Brick Masonry	-	$E\ m = 1014 * f'_m$	-
FEMA 356 [8]	-	-	$E_m = 550 * f'_m$	-

4 CONCLUSION

Following conclusions can be drawn on the basis of results of this research study:

- Compressive strength of masonry depends on the compressive strength of masonry units and number of joints. Greater the compressive strength of masonry unit, greater will be the compressive strength of masonry whereas greater the number of joints in a square unit, lesser will be the compressive strength of masonry and vice versa.
- Compressive strength of masonry was found to be 42% of that of masonry unit in case of brick masonry whereas 49% in case of concrete block masonry respectively.
- Elastic modulus of masonry was found to be 520 times its compressive strength in case of brick masonry whereas 625 times in case of concrete block masonry respectively.

- Shear modulus of masonry was found to be 41% of that of elastic modulus in case of brick masonry whereas 39% in case of concrete block masonry respectively.
- Poisson's ratio was found to be 0.2383 for brick masonry whereas 0.3127 for concrete block masonry.

ACKNOWLEDGMENT

The authors would like to thank everyone who helped us in our research work, particularly the lab staff of concrete laboratory, Department of Civil Engineering, CUI, Abbottabad Campus for their cooperation in carrying out experimental work. The authors also like to express special thanks of gratitude to the research supervisor Engr. Asif Shahzad and co-supervisor Engr. Tayyaba Bibi for providing their invaluable guidance throughout the research. Their dynamism, vision, sincerity and motivation have deeply inspired us.

REFERENCES

[1] S. Sattar and A. B. Liel, "SEISMIC PERFORMANCE OF REINFORCED CONCRETE FRAME STRUCTURES WITH AND WITHOUT MASONRY INFILL WALLS," *9th US National and 10th Canadian Conference on earthquake engineering.*, p. 10, 2010.

[2] S. Phaiju and P. M. Pradhan, "Experimental work for mechanical properties of brick and masonry panel," *J. Sci. Eng.*, vol. 5, pp. 51–57, Aug. 2018, doi: 10.3126/jsce.v5i0.22372.

[3] T. C. Nwofor, "EXPERIMENTAL DETERMINATION OF THE MECHANICAL PROPERTIES OF CLAY BRICK MASONRY," vol. 3, no. 3, p. 20, 2012.

[4] Ž. Radovanović, R. S. Grebović, S. Dimovska, N. Serdar, N. Vatin, and V. Murgul, "The Mechanical Properties of Masonry Walls - Analysis of the Test Results," *Procedia Eng.*, vol. 117, pp. 865–873, 2015, doi: 10.1016/j.proeng.2015.08.155.

[5] P. Brandão, H. Ramos, and C. de Souza, "STRESS-STRAIN BEHAVIOR OF CONCRETE BLOCK MASONRY PRISMS UNDER COMPRESSION," p. 8, 2012.

[6] S. Arash, "MECHANICAL PROPERTIES OF MASONRY SAMPLES FOR THEORETICAL MODELING," p. 10, 2012.

[7] C15 Committee, "Test Method for Compressive Strength of Masonry Prisms," ASTM International. doi: 10.1520/C1314-18.

[8] "FEMA 356 Prestandard and Commentary for the Seismic Rehabilitation of Buildings," p. 519, 2000.

EVALUATION OF HALF-THROUGH BRIDGE LOAD-CARRYING CAPACITY BY USE OF NON-LINEAR ANALYSIS METHODS – CASE STUDIES

Furqan Qamar[a], Kirils Grube[b] and Andreas Triantos[c]
a: Corresponding Author. Principal Engineer WSP UK.Email: furqan.qamar@wsp.co.uk
b: Engineer, WSP UK
c: Assistant Engineer, WSP UK

Abstract- UK's existing railway network relies on many half-through bridges that were built during Victorian era and are already beyond their designated service life. Therefore, maintaining bridge assets in serviceable condition to ensure sustainable replacement rate without major network disruptions is vital. Current UK practice applies the British Standards and Network Rail's assessment codes to quantify the load capacity of such bridges using hand methods. If the codified methods rate the bridge capacity as substandard more advanced analysis (based on finite elements) is usually commissioned in an attempt to improve the capacity. In this advanced analysis the structure is modelled with 3D shell elements and the load group rating is extracted from a non-linear buckling and plastic analysis. Currently, there is not enough formal guidance regarding the pre-processing and more importantly the post-processing techniques of a FEA based assessment and quite often the knowledge and experience is passed over solely from more experienced individuals. This paper presents two case studies of real half-through bridges that demonstrate how additional FE model refinement, mainly through convergence enhancements, could reveal essential information about bridge behavior at or close to collapse load. Based on findings from the case studies, a set of generic recommendations is produced to inform both pre- and post-processing aspects of future assessments where bridge capacity is extrapolated directly from FE model results. The main aim of this paper to add more clarity in the interpretation of Nonlinear Analysis results. This can lead to more appropriate maintenance or strengthening recommendations and savings in the budget.

Keywords- Half-through, Finite element model, Non-linear analysis, Network rail.

1 INTRODUCTION

Bridges play a vital role in supporting railway infrastructure in the UK. Out of 30,000 bridges owned by Network Rail (NR), one third of them are of metallic composition such as steel, wrought iron and cast iron [1]. One of the most common configurations for metallic bridges encountered on railway is the 'half-through' type shown on Figure 1 (a) [2]. This form of construction is preferred on railway sites over others for its distinct positioning of trafficked surface with respect to the structural envelope. As opposed to other deck types, the trafficked surface lies within construction depth of a deck which allows to partially accommodate track components and traffic within deck boundaries, resulting in greater clearances beneath a bridge. The drawback is that only U-frame action provides lateral restraint at the level of compression flange, making this deck type susceptible to torsional buckling. A large fraction of 'half-through' type bridges, constructed during Victorian era, have detailing which renders U-frame action partially ineffective. An example of such detail is a non-coincident position of cross girder with respect to web stiffener as shown on Figure 1 (b). With non-utilised U-frames, the spacing of lateral restraints, i.e. effective length, becomes equivalent to girder span. This results in a massive increase of compression flange slenderness and reduced bending capacity of a girder, as evident from Figure 1 (c). Moreover, many investigations [3] demonstrate that standard rules for girder web and stiffener capacities are unduly pessimistic. Unsurprisingly, many old bridges fail assessments undertaken by codified hand methods.

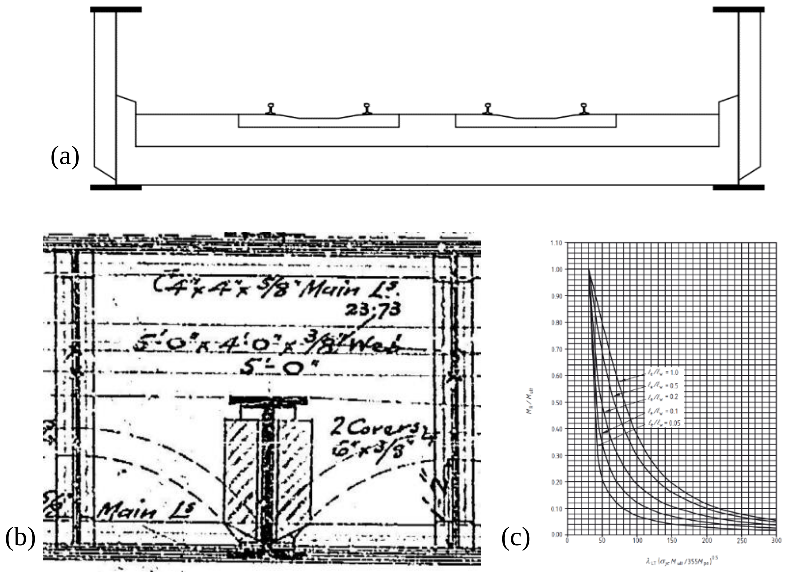


Figure 8: (a) Example of half-through construction [2] (b) Cross girder not coincident with web stiffeners in the bridge built circa 1900; (c) Chart indicating relationship between girder slenderness and limiting moment of resistance, MR [4]

For bridges that have been rated as sub-standard by codified hand assessment, NR usually commissions a more advanced assessment, utilising Finite Element Analysis (FEA) where girder capacities are extrapolated directly from a FE model (primary shell). Some bridges with peculiar geometric features, e.g. fish-bellied geometry of girders, high skew, slanted girders on plan, bypass codified hand assessment if asset owner deems that hand methods are unsuitable. FEA assessments rate individual girder elements against buckling and yielding. The governing buckling modes in U-frame bridges are lateral torsional buckling to the compressive flange and shear buckling of web plates. Web plates are normally accompanied by transverse stiffeners to enhance web's post-buckling capacity due to tension field action [5]. Buckling of plate structures is characterised by biaxial bending due to out-of-plane deflection of the elements. In contrast with axially loaded columns where buckling limits their ability to support more than the critical axial load, plates under compression will continue to support higher axial forces by utilising membrane action and they will fail in loads significantly higher than the theoretical critical load [6]. Additionally, in the design of new bridges, it is common to first size the structure for strength and stiffness and then carry out SLS and ductility checks over the remaining capacity, whereas target deflections and fatigue criteria can be used as a benchmark in determining reserve capacity of existing bridges. Similar to seismic or other complex designs some degree of plastic structural response can be expected when assessing old bridges under service loading. This relies on the inherent ductile properties and slenderness of steel and wrought iron girders that allow for internal redistribution effects [10,11]. However, plastic deformations are generally avoided in the assessment of existing old bridges because it is difficult, in practise, to define a point at the load-displacement curve where the reduction of the load-carrying capacity can be deemed as acceptable.

Many Victorian era bridges are well beyond their design life yet continue to demonstrate resilience against NR's performance metrics for safety and reliability. Numerous of these bridges are in poor condition with highest proportion (~33%) scattered over Scotland route [7]. Condition of bridges will continue to deteriorate and, eventually, replacements will need to be commissioned. NR strategic plans for Control Period 6 [8] highlight how unsustainable the current rates of remediation are and how it will have a knock-off effect on railway network capability in the future. For example, with Wessex route, at the present replacement rate, it is projected that some of the bridge assets will be 300 years old before they can be replaced [8]. This suggests that more influx of funding will be required to either increase the replacement rate or maintain old bridges in serviceable condition. In order to prioritise bridge replacements in a sustainable manner, improvement in the assessment reporting is required to ensure that replacement scheme appraisals are not driven by inconclusive results.

Guidance on conducting non-linear assessments of NR bridges primarily lays emphasis on pre-processing aspects of FEA bridge modelling. A research gap has been identified in the post processing requirements which, in UK practice, are limited to examples of load-displacements charts and screenshots of yield labels on stress contours at the locations of interest. With the aid of two real bridge examples, in order to address the research gap this paper demonstrates that by blindly executing the assessments to the guidance requirements may lead to erroneous conclusions. The aim of this paper is to add more clarity to the interpretation of post-processing NL analysis results and to highlight the significance of buckling displacement history in extrapolating bridge load carrying capacity.

2 METHODOLOGY

2.1 General formulation of bridge models for analysis

3D thick shell FE LUSAS v17.0 models of two real half-through bridges, Grand Union Canal and Battersby Lane, are used to investigate buckling behaviour of web panels. Shell thickness of surfaces in both models accounts for corrosion section losses that have been rationalised from inspection reports. A non-linear buckling analysis is undertaken in two steps, incorporating both geometric and material non-linear characteristics described in Section 2.2 and 2.3 respectively. First analysis step includes application of permanent actions as a single load increment. In the second step, it is intended to inherit residual stresses and deformation contour from first step and apply rail traffic at 0.05 load increments. A 0.05 increment represents each load group number in RA (route availability) 0-15 range, capturing all locomotive classes that are used in the UK. Articulation is assigned to suit bearing conditions of each bridge (bottom flange bearings seated directly on bedstones) – simply supported arrangement with restraints applied at centre line of bearing stiffener. As the selected bridges experience convergence issues early into the non-linear analysis, model refining is undertaken to alleviate stress concentrations in the bearing zones. Slide surfaces are used in Grand Union Canal Bridge to idealise contact between bedstones and bottom flanges and lift-off support capability is incorporated in Battersby Lane Bridge. Table 1 and Figure 2 below showcases the LUSAS shell models and the key characteristics of the bridges that are analysed.

Table 1: Key characteristics of bridges analysed

Bridge Name	**Bridge Span (m)**	**Bridge Width (m)**	**Girder Depth (m)**	**Skew**	**Material**	**U-frame notes**
Grand Union Canal	27.3	6.8	1.40	67°	Wrought Iron	Partial compression flange restraint provided by unstiffened moment connection between transverse and main girders. Transverse beams are not coincident with stiffeners.
Battersby Lane	22.0	12.0* (average)	2.25	50°	Wrought Iron	Compression flange restraint provided by stiffened moment connection between transverse and main girders. Transverse beams and stiffeners form an effective U-frame.

*Width varies along the bridge due to slanted alignment of girders on plan

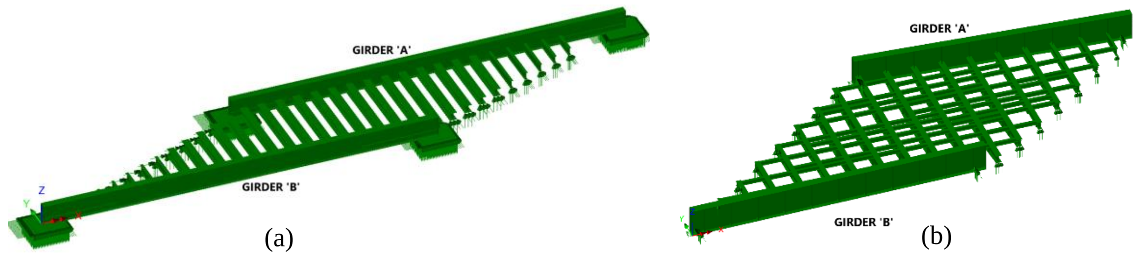


Figure 9: (a) Grand Union Canal LUSAS Shell Model; (b) Battersby Lane LUSAS Shell Model. Floor deck excluded for clarity

2.2 *Prescribed initial perturbations*

Non-linear buckling analysis is undertaken with initial deformations generated by web buckling modes from elastic eigenvalue analysis. Magnitudes for displacements are be derived in accordance with Table 8 in BS 5400-6 [12]. Displacement path has significant weight on how RA load group number for capacity is derived and it is undesirable to introduce excessive initial deformation especially if it has not been observed on site. The scale of imperfection only needs to be enough for triggering anticipated buckling behaviour.

2.3 *Materials*

The plasticity models that are more suitable for ductile materials which exhibit little volumetric strain such as isotropic metals are typically that of von Mises and Tresca. Both can appear side by side with little or no difference depending on complexity. Calibration of both criteria with respect to tensile (or compressive) strength and shear strength has shown that the maximum difference between the two is approximately 15% which, compared to assessment or design safety factors is relatively small. Von Mises plasticity criterion is selected for model material attribute which in contrast to the more conservative Tresca (lower limit) is considered as more consistent to experimental data and more widely accepted for civil engineering applications [9]. Elastic-Perfectly-Plastic material is also assumed. A strain hardening gradient is assigned in the plastic material properties to further refine the model and improve convergence. A plastic strain limit is set at 0.15 (15% elongation) according to NR/GN/CIV/025 which applies to wrought iron materials that have not been tested. The slope (E2) of the hardening gradient has been calculated using equation 1 as follows:

$$E2 = ((\sigma_u - \sigma_y) / (\delta_2 - \delta_2) \qquad (1)$$

Where: E= Modulus of Elasticity; σ_u *= ultimate tensile strength;* σ_y *= minimum yield strength;* $\delta_1 = \sigma_y/E$*;* $\delta_2 = 0.15$

2.4 *2.4 Post processing and interpretation of results*

Instead of following the scope prescribed in the Level 2 assessment guidance document which indicates RA0-15 (14t-31t) axle load range for non-linear analysis, the FE models are refined to improve convergence and run extended non-linear analysis with more increment steps with loading beyond RA0-15 range. The intent is to investigate whether there is any benefit of overloading a bridge deck to extract a more informative post-buckling displacement history graph.

3 RESULTS AND DISCUSSION

3.1 *Grand Union Canal Bridge – sensitivity of buckling response to articulation*

As described in section 2, a non-linear finite element model is developed for Grand Union Canal bridge. This case illustrates how the use of non-linear boundary conditions have allowed to run a more extensive analysis and evaluate behaviour from larger pool of results. Figure 3 (a) shows the load-displacement curve at the critical web panel using basic linear support conditions. Due to peak stress concentrations at the nodes restrained by simple supports, convergence issues aborted the analysis early and engineer rated the bridge as substandard (RA0; <14t per axle) governed by buckling of web panel adjacent to obtuse corner bearing. This was followed by recommendations for immediate speed and load restrictions across the structure. Evaluation of the boundary conditions using NL slide line supports with contact surfaces to distribute the load over a more 'realistic' area enhanced solvability of the model at the latter load increments.

Figure 3 (b) shows how the displacement history of buckling response for the same element was extended to capture the non-linear behaviour up to factor of 3.0x. Moreover, as snap-through buckling behaviour is not identified in the refined analysis, it highlights how buckling response is sensitive to articulation attributes. As a result, sufficient displacement range allowed to extrapolate conclusive load group for buckling (RA6; 20t-22t per axle, a 42%-57% increase).

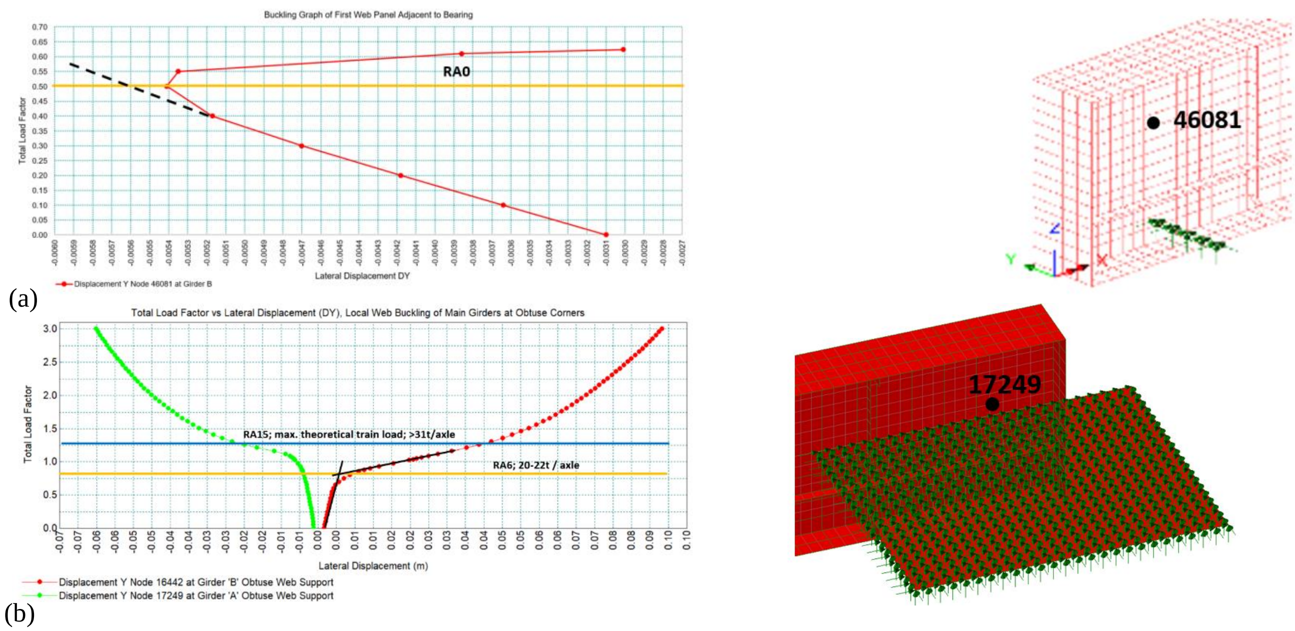


Figure 10: Web buckling behaviour at obtuse corners of the girders. (a) Simple support conditions; (b) Slideline surfaces.

3.2 Battersby Lane Bridge – a case with two local buckling modes with inherently different behaviours

This case demonstrates two local buckling modes obtained from web panels at the opposite obtuse corners of Battersby Lane Bridge. Figure 4 shows displacements paths against load increments for two non-linear analyses undertaken for main girder webs. The analyses have been prescribed with initial perturbations with maximum displacement applied to node 15274 which has been identified by elastic eigenvalue buckling analysis. The only difference between the two analyses sets is the extent of displacement history. Figure 4 (a) graphs cover displacements up to 1.25 load factor which is equivalent to RA15, whilst Figure 4 (b) proceeds beyond load factor of 2.0 to capture displacements from higher load increments.

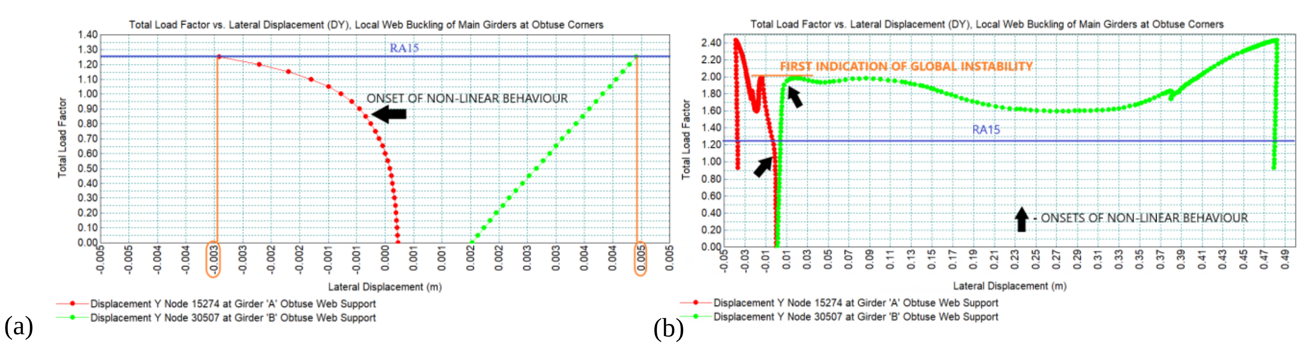


Figure 11: (a) Non-linear buckling analysis 1, last load increment at factor 1.25 x RA1 live load; (b) Non-linear buckling analysis 2, highest load increment peaks at ~2.4 x RA1 live load.

From Figure 5 (a) it is clear that commencement of non-linear behaviour for node 15274 occurs within 0.7-0.9 load factor range. The displacement path peaks at 3mm at the last load increment (1.25x) and signals the development of gradient plateauing. In contrast, node 30507 shows no signs of non-linear behaviour within 0-1.25 load factor range yet its displacement peaks at 5mm. However, Figure 4 (b) illustrates that curve flattening at node 15274 is within narrow displacement range if compared to maximum displacement at node 30507. It is also evident that buckling at node 15274 does not evolve into collapse load and does not show any signs of instability before sudden flattening at node 30507. This suggests that buckling at node 30507 triggers global instability and earlier commencement of non-linear path at node 15274 does not warrant reporting of bridge failure as highlighted by Ryjacek, 2019. This conclusion is reinforced by observing non-amplified displacement contours shown on Figure 5 that shows how buckling at node 30507 (Figure 5 (a)) evolves into plastic collapse of the girder, whilst displacement at node 15274 (Figure 5 (b)) remains small with respect to adjacent elements.

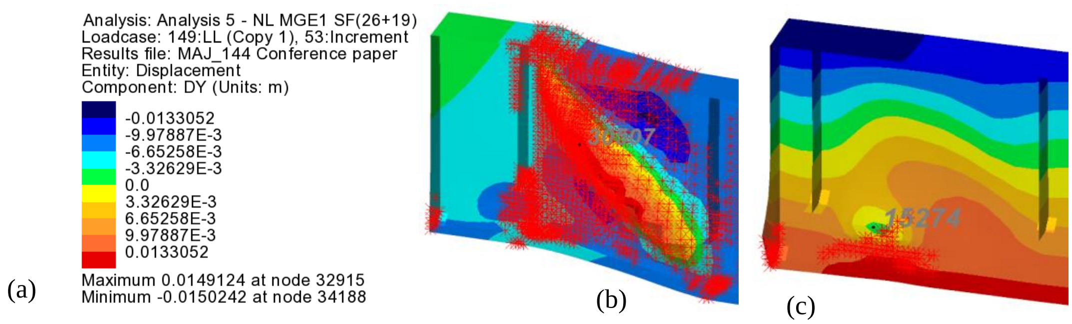


Figure 12: Displacement contours at buckled panels at load increment 2.0 x RA10 railway live load (non-amplified). Red crosses indicate yielded mesh. (a) Contour legend; (b) Node 30507, buckling at obtuse end of Girder 'B', signifying tension field action; (c) Node 15274, localised buckling at obtuse end of Girder 'A'.

4 Conclusion And Recommendations

Non-linear buckling analysis results for web panels of two bridges have been presented in this study. Following conclusions are drawn from this study:

- Through additional refinement of models to enhance solvability, it has been revealed that interpretation of results could vary depending on the quantity of data, primarily displacement history. With the bridges analysed, inadequate displacement range has led to erroneous capacity reporting.
- It has also been demonstrated how buckling response is sensitive to idealised boundary conditions and that further refinement of articulation can eliminate 'dummy' buckling modes. In addition, as demonstrated by review of Battersby Lane Bridge results, eigenvalue buckling analysis is not always a reliable predictor of critical buckling modes.
- Not all these matters are considered in the guidance note for undertaking advanced Level 2 assessments which has led to reporting of overly conservative results

To avoid potential erroneous reporting in the future, the following recommendations are made:

- The minimum threshold limits for buckling displacement history should be defined in the guidance document. From case studies presented in this paper, it is clear that 5mm displacement range is too narrow to make an informed judgement. Through inspection of graphs on Figure 3 (b) and 4 (b), 10mm lateral displacement range for local buckling of web should be sufficient to provide a plot from which load group against web buckling failure could be determined. Displacement range for flanges requires a separate study as flanges can undergo much larger lateral deformations before stability of the whole bridge is compromised.

- For complex bridges, provisions for further sensitivity analyses to resolve convergence issues or improve results should be discussed and be considered in advance. Ideally additional budget will be included during the bidding stages solely for that. Bridges with large spans and excessive skew may take hours to complete one single analysis which has resulted in engineers taking shortcuts in order to complete the work within budget.
- The scope of assessment should incorporate a more in-depth discussion of appropriate remediation measures for the failure mode under consideration. For example, it should be outlined which intervention strategy, such as planned preventative, do nothing, aggressive monitoring etc., best fits the behaviour of governing element. Having visibility of post-buckling reserve capacity would help to identify the urgency of strengthening or maintenance measures.

ACKNOWLEDGMENT

The authors would like to thank WSP UK Ltd as an organisation to give opportunity to carry out this study. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] Network Rail, "NR Bridge List.xlsx," 2015.
[2] D. C. Iles, "Design Guide for Steel Railway Bridges," Ascot, The Steel Construction Institute, 2004, pp. 13-43.
[3] C. R. Hendy and F. Presta, "Transverse web stiffeners and shear moment interaction for steel plate girder bridges," in Portugal, Guimarães, 2008.
[4] British Standard Institution, "BS 5400-3:2000. Steel, concrete and composite bridges - Part 3: Code of practice for design of steel bridges," London, 2000.
[5] SCI, "Design Guide for Steel Railway Structures," Ascot, Berkshire, The Steel Construction Institute, 2004, p. 164.
[6] ICE, "ICE Manual of Bridge Engineering (Second Edition)," London, Thomas Telford Ltd, 2008, p. 735.
[7] Network Rail Scotland Route, "Scotland Route Strategic Plan," Network Rail, 2019, pp. 89-90.
[8] Network Rail Wessex Route, "Wessex Route Strategic Plan | 2019 to 2027," Network Rail, 2019, p. 111.
[9] N. E. Dowling, Mechanical Failure of Materials 4th Edition, Blacksbury, Virginia : Pearson, 2012.
[10] W.-F. Chen and L. Duan, "Bridge Engineering Handbook Second Edition (Seismic Design)," Boca Raton, Florida , Taylor & Francis Group , 2014, p. 722.
[11] R. Karoumi, J. R. Casas, M. Plos, C. Cremona, C. melbourne and J. S. Jensen, "Guideline For Load and Resistance Assessment Of Existing European Railway Bridges," 4th International Conference on Bridge Maintenance, Seoul S. Korea, 2008.
[12] British Standard Institution, "BS 5400-6:2000. Steel, concrete and composite bridges - Part 6: Specification for materials and workmanship, steel;," London, 2002.
[13] P. Ryjacek, The diagnostic techniques for the assessment of the historical steel bridges, *IABSE Symposium, Guimaraes 2019: Towards a Resilient Built Environment Risk and Asset Management – Report*, pp. 1651-1657.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

MACHINE VISION BASED CRACK DETECTION FOR STRUCTURAL HEALTH MONITORING USING HARALICK FEATURES

[a] Arif Zafar, [b] Junaid Mir, [c] Vagelis Plevris, [d] Afaq Ahmad
a: Department of Electrical Engineering, University of Engineering and Technology Taxila, Pakistan, arifzafar966@gmail.com
b: Department of Electrical Engineering, University of Engineering and Technology Taxila, Pakistan, junaid.mir@uettaxila.edu.pk
c: Department of Civil Engineering and Energy Technology, OsloMet- Oslo Metropolitan University, Norway, vageli@oslomet.no
d: Department of Civil Engineering, University of Engineering and Technology Taxila, Pakistan, afaq.ahmad@uettaxila.edu.pk

Abstract- Crack detection in structural elements is pivotal for structural health monitoring. In this paper, an automatic machine vision-based crack detection method is proposed, which is efficient, computationally simple, and fast in contrast to the time-consuming and highly subjective traditional visual inspection approach. Textural analysis of the concrete surface image is performed using Haralick features for crack detection. First, a combination of 8 suitable Haralick features in 4 different directions are extracted from the SDNET2018 image dataset. Then, different SVM classifiers are trained on the extracted features and tested using a 5-fold cross-validation scheme to distinguish between cracked and non-cracked images. The resulting best-trained classifier achieves an overall classification accuracy of 88%. Furthermore, the high classification accuracy for individual image categories indicates that the proposed method can effectively detect cracks in the images. Finally, crack orientation is localized based on the extracted feature values.

Keywords- Crack detection, Haralick features, structural health monitoring, machine learning

1 INTRODUCTION

Concrete cracks are generally unavoidable and very common due to expansion, shrinkage, overloading, settlement, or premature drying, which are common causes of cracks in the concrete surface. While concrete cracks are not always associated with high risk, they are nevertheless the first indicators of compromised structural durability and health. Therefore, the detection and assessment of crack properties, such as width, orientation, and its precise location in the structure, is crucial for structural health monitoring (SHM). Visual inspection by a trained inspector is the conventional method for crack detection which is highly subjective of the person's experience and knowledge. More importantly, visual inspection is a particularly time-consuming and labor-intensive approach. Therefore, several reliable and cost-effective machine vision (MV) based automatic crack detection and assessment techniques have been proposed in the literature as a substitute for the traditional human visual inspection approach for SHM [1].

MV-based SHM techniques mostly rely on the camera image for concrete crack detection. As the crack in a 2D image is characterized by an edge, these methods generally employ edge detection and segmentation algorithms for the detection of cracks in the concrete surface image. In [2], probabilistic relaxation with adaptive thresholding is proposed for crack detection. A pavement crack detection method: CrackTree [3], detected cracks from the crack probability map constructed through the tensor voting scheme after the correction of illumination using the geodesic shadow removal technique. A phase symmetry-based enhancement filter coupled with morphological operations and thresholding is proposed in [4] for concrete crack detection. In [5], cracks are detected by using the Sobel edge detector and OTSU thresholding scheme. This method was further extended in [6], where the connected component analysis was performed in HSV colorspace to detect cracks. In [7], the Sobel edge detector, morphological operations, and particle filter are employed for crack detection. A bottom-hat morphological operation is used in [8] for the detection of crack and surface degradation. A machine learning (ML) centered method is proposed in [9] where a classifier trained on the histogram of oriented gradient features is used for crack detection. A similar approach is presented in [10], where a trained classifier on speeded-up robust descriptors is utilized for the classification of images into cracked and non-cracked images. In [11], crack detection using small drones is proposed by using a deep learning (DL) neural network approach. AlexNet convolutional neural network (CNN) is trained using a transfer learning approach to classify acquired camera images from the drone into cracked and non-cracked images. A method in [12] is also based on the AlexNet CNN, where an exhaustive search with a sliding window is utilized to detect cracks using a smartphone application. In [13], a semantic segmentation is performed to accurately detect crack pixels using a visual geometry group network (VCGNet) based CNN.

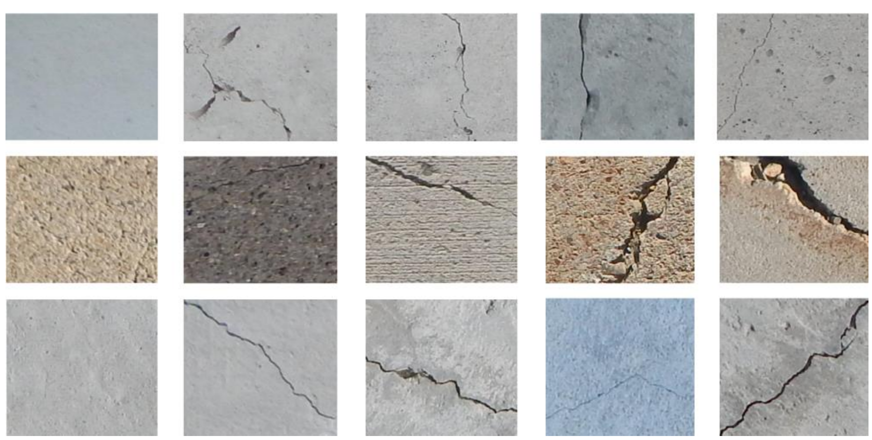
The existing MV-based crack detection techniques are generally conditional variant due to pixel-based detection of cracks. Therefore, their performance is seriously compromised due to different light conditions, blemishes and concrete spalls. On the other hand, accuracy of DL-based crack detection methods is largely dependent on the quality and quantity of the utilized training dataset. In the present paper, a MV-based method for the automatic detection of cracks from the camera images is presented, which relies on the concrete surface texture analysis as a suitable measure for crack detection. For ameliorating this, Haralick features are initially extracted from the diverse database of the cracked and non-cracked concrete surface images. Then, the ML-based classifiers are trained and tested on the extracted features for crack detection. The trained classifier on the extracted features achieves high classification accuracy for crack detection. In contrast to existing techniques, the proposed method is based on the global robust features, and therefore, the performance of the proposed method is invariant to image translation, rotation, scale, and illumination.

The remainder of the paper is organized into four sections. In Section 2, the materials and methods utilized in the proposed technique are presented. The proposed methodology is detailed in Section 3. Results are discussed in Section 4, and the conclusions and future work is presented in Section 5.

2 MATERIALS AND METHODS

2.1 Materials

The required material for this study is the concrete images of different civil structures annotated as cracked or non-cracked. For this purpose, SDNET 2018 is utilized, which is a publicly available comprehensive dataset of more than 56,000 camera images of concrete walls, pavements, and bridges [14]. The images in the dataset (as detailed in Table 1) are labeled and categorized into two image classes: cracked and non-cracked. SDNET2018 is a challenging and diverse dataset as it includes images with different illumination conditions and obstructions. Further, it includes images of different crack widths ranging from 0.06 mm to 25 mm. Figure 1 shows some of the SDNET2018 images of different conditions and cracks widths. For our method, we have pre-selected images (as detailed in Table 1) for each class (cracked and non-cracked) from each category. The selection was primarily done to balance the classes and more importantly, to remove images having barely visible cracks or cracks within tolerable crack width as per guidelines of American concrete institute (ACI) [15].



(a) (b) (c) (d) (e)

Figure 1: SDNET2018 image dataset: Non-cracked (a) and cracked (b-e) sample images with different crack widths and lighting conditions of walls (top row), pavements (middle row), and bridge decks (bottom row).

Table 1- Details of original SDNET2018 and Utilized image dataset.

Category	SDNET2018			Utilized dataset (Selected Images)		
	Cracked images	**Non-cracked images**	**Total**	**Cracked images**	**Non-cracked images**	**Total**
Bridge deck	2025	11,595	13,620	960	960	1920
Pavement	2608	21,726	24,334	964	964	1928
Wall	3851	14,287	18,138	960	960	1920
Total	8484	47,608	56,092	2884	2884	5768

2.2 *Haralick Features*

Haralick features are extracted from the gray-level co-occurrence matrix (GLCM) [16]. GLCM matrix is the statistical method of examining texture based on the spatial relationship of the pixels. The normalized and symmetric GLCM matrix is computed by calculating how often a pixel with a grayscale value *i* occurs with a specific pixel offset and direction to a pixel with the grayscale value j. For our proposed method, we have selected 8 Haralick features out of 14. The selected features are: *Contrast*, *Angular second moment (ASM)*, *Energy*, *Dissimilarity*, *Homogeneity*, *Entropy*, *Correlation*, and *Variance*, which were the most suitable ones for the texture analysis of the concrete crack surface. The mathematical expressions for these features are presented in Table 2, where $I(i,j)$ is the GLCM matrix of size $N \times M$ with i and j index values, μ is the mean value and σ_x and σ_y are the standard deviation in the x and y directions, respectively.

Table 2- Selected Haralick features.

Feature	Expression	Feature value in presence of Crack
Contrast	$\sum_{i,j}^{N-1}(i-j)^2 * I(i,j)$	Higher value
ASM	$\sum_{i,j}^{N-1}[I(i,j)]^2$	Lower value
Energy	$\sqrt{ASM}$	Lower value
Dissimilarity	$\sum_{i,j}^{N-1}\lvert i-j\rvert * I(i,j)$	Higher value
Homogeneity	$\sum_{i,j}\frac{I(i,j)}{1+\lvert i-j\rvert}$	Lower value
Correlation	$\sum_{i,j}^{N-1}\frac{(i,j) * I(i,j) - \mu_x * \mu_y}{\sigma_x * \sigma_y}$	Lower value
Entropy	$-\sum_{i,j}^{N-1} I(i,j) * \log I(i,j)$	Higher value
Variance	$\sum_{i,j}^{N-1}(i-\mu)^2 * I(i,j)$	Higher value

3 PROPOSED METHODOLOGY

The block diagram of the proposed MV-based crack detection method from the concrete surface images is depicted in Figure 2 with the details presented below. The processes involved in the proposed methodology were implemented and executed using MATLAB and Python computer programming languages.

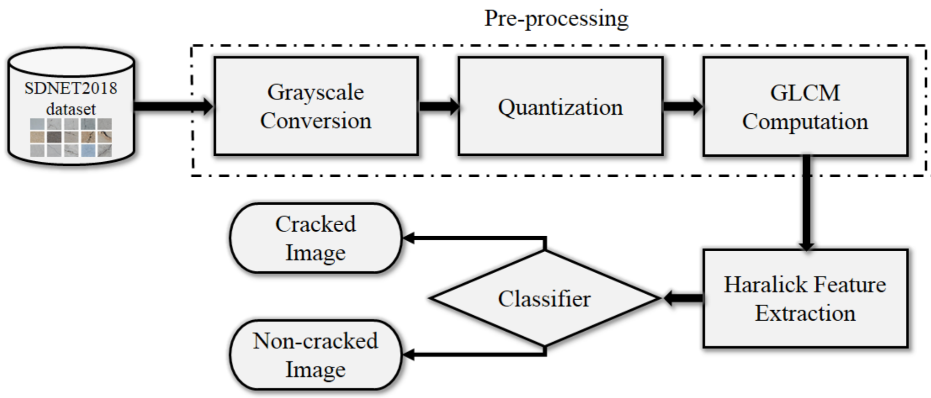


Figure 2: Block diagram of the proposed method.

3.1 *Pre-processing*

The color concrete surface image is first converted to grayscale format using a linear transformation. Then, the image is quantized to 12 grey levels which were found enough for retaining the cracks with sufficient detail. The resulting quantized grayscale image was an accurate approximation of the original 256 grey level image. The quantization was done to facilitate the computation of GLCM as it is computationally very expensive to calculate GLCM for all 256 grey levels. After the quantization, GLCM is computed with a pixel offset of 1 for four angles (0˚, 90˚, 45˚ and 135˚), corresponding to four directions: the horizontal, the vertical, and the two diagonals, respectively.

3.2 *Haralick Feature Extraction*

Selected Haralick features (as detailed in Section 2.2) are extracted from the GLCM. Out of the 8 features, 6 features (except *Entropy* and *Variance*) will have 4 values from 4 different directions. Therefore, the resulting feature vector length is 26. Further, the main orientation of the crack can be observed by analyzing the feature values in four different directions as there is a distinct discrepancy present among GLCMs generated at different angles. Cracks are generally oriented along with local minima or maxima of that individual feature, depending on the behavior of feature in the presence of the crack.

3.3 *Classifier*

A support vector machine (SVM) is used as a classifier for training and testing the proposed method. SVM is a global classifier suitable for fitting multi-class data distribution. Based on the kernel, it can perform both linear and non-linear fitting for classification. For linear classification, a suitable hyper plane divides each cluster equally by the support vectors. While in non-linear classification, it transforms the initial distribution to a higher dimension where they are separable. The tested kernels included *radial basis function (RBF)*, *Histogram intersection (HI)* and *linear*. For training and testing the SVM kernels, k-folds cross-validation scheme was utilized. The data were randomly partitioned into k equal sets and then the classifier is trained on $k-1$ sets with remaining 1 set left out for testing. The process is repeated for each set and the final accuracy is collectively calculated for the complete set. The value of k was 5 in our method.

4 RESULTS AND DISCUSSION

To quantify the performance of the trained classifier for crack detection, *Accuracy* (*Acc.*), *Recall* (*R*), *Precision* (*P*) and *F1-score* (*F1*) are computed. Table 3 presents the utilized performance metrics where *TP* is True Positive: a cracked image correctly classified as a cracked image, *TN* is True Negative: a non-cracked image correctly classified as a non-cracked image, *FP* is False Positive: a non-cracked image incorrectly classified as a cracked image, and *FN* is False Negative: a cracked image incorrectly classified as a non-cracked image.

Table 3- Performance metrics.

Metrics	Mathematical Expressions
Accuracy (%)	$Acc. = \frac{TP + TN}{TP + TN + FP + FN} \times 100$
Recall (%)	$R = \frac{TP}{TP + FN} \times 100$
Precision (%)	$P = \frac{TP}{TP + FP} \times 100$
F1-score (%)	$F1 = \frac{2 \times P \times R}{P + R} \times 100$

Table 4 presents the 5-fold cross-validation results in terms of *Acc.*, *R*, *P*, and *F1* of the tested classifiers for individual categories and all categories combined. It can be observed that the *HI*-based SVM classifier has the maximum performance metric values for individual categories. The proposed method can distinguish between cracked and non-cracked images with an accuracy of 88% for bridge deck surface images, 94% for pavement surface images and 89% for wall surface images. Further, when all categories are combined, the proposed method has a classification accuracy of 88% and the best-trained model is a *Linear*-based SVM classifier.

Table 4- Performance evaluation of the proposed method. 5-fold cross-validation results of SVM kernel-based classifiers trained on each image category and all images combined.

Category		Bridge deck			Pavement			Wall			All		
SVM kernel		*RBF*	*HI*	*Lin*	*RBF*	*HI*	*Lin*	*RBF*	*HI*	*Lin*	*RBF*	*HI*	*Lin*
Metrics	*Acc.* (%)	74	***88***	88	88	***94***	92	66	***89***	88	64	57	***88***
	R (%)	66	***85***	84	84	***93***	91	74	***89***	87	74	59	***86***
	P (%)	77	***91***	91	91	***95***	93	57	***89***	88	59	55	***90***
	F1 (%)	70	***88***	87	87	***94***	92	64	***89***	88	65	56	***88***

After the crack detection by a trained classifier, the extracted Haralick feature values in four directions are assessed to localize the main orientation of the crack in the image. While all extracted Haralick features show a distinctly different value along the direction of the crack orientation in comparison to the other directions, we have found the *contrast* as the most suitable feature for the localizing the main direction of the detected crack in an image. Therefore, the crack's main orientation is ascertained by finding the maximum value of the *contrast* feature. To elaborate on this, Figure 3 shows two sample images with 135˚ and 45˚ crack orientations. The corresponding four *contrast* feature values calculated from GLCMs for these two images are tabulated in Table 5. As GLCMs have distinct discrepancies among themselves in the presence of a crack, this is reflected in the computed feature values. Figure 3(a) has the maximum *contrast* feature value of 2.36215 for GLCM computed at an angle of 135˚. Therefore, the main orientation of the detected crack in the image is the diagonal direction of 135˚. Similarly, the maximum contrast value for Figure 3(b) is 3.80787 for computed GLCM at 45˚angle, which is indeed the main direction of the crack orientation in the image.

(a) (b)

Figure 3: (a) Cracked image with 135˚ crack orientation (b) Cracked image with 45˚ crack orientation.

Table 5- Haralick *Contrast* feature values for sample images in Figure 3.

***Contrast* Values**	**GLCM Angles**			
	0˚	**45˚**	**90˚**	**135˚**
Figure 3 (a)	1.49887	1.74825	0.87333	***2.36215***
Figure 3 (b)	2.67880	***3.80787***	1.10470	2.80471

Finally, the performance comparison of our proposed method is made with a recent study in [17], where six different MV-based algorithms are benchmarked for crack detection in concrete surfaces. Among the tested algorithms, the crack detection in spatial domain using Laplacian of Gaussian (LoG) filter proved to be the best performing technique for concrete crack detection. While the rest of the evaluated algorithms had a classification accuracy of below 85% [17], the LoG-based algorithm yielded a similar performance with 92% accuracy with 88% precision, which is comparable with our proposed method. However, the performance of the algorithm is reported on an image dataset size of 100 images of concrete panels only.

5 CONCLUSION

The following conclusions can be drawn from the conducted study:

- An automatic crack detection from concrete surface images of different civil structures can be made using advanced machine vision techniques.
- Crack detection can be done through textural analysis of the concrete surface image using a combination of appropriate Haralick features.
- Crack orientation can be determined by assessing the extracted features in different directions.

The proposed method shows a good classification accuracy for cracked and non-cracked images which motivates us to explore other Haralick features in future works. The proposed method can be integrated with unmanned aerial vehicles (drones) for autonomous concrete crack detection. Also, more robust pre-processing steps can be examined to enhance the region of interest to improve the crack detection and thereby, further improve the classification accuracy.

ACKNOWLEDGMENT

The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] Arun Mohan and Sumathi Poobal. Crack detection using image processing: A critical review and analysis. *Alexandria Engineering Journal*, 57(2):787–798, 2018.

[2] Yusuke Fujita and Yoshihiko Hamamoto. A robust automatic crack detection method from noisy concrete surfaces. *Machine Vision and Applications*, 22(2):245–254, 2011.

[3] Qin Zou, Yu Cao, Qingquan Li, Qingzhou Mao, and Song Wang. CrackTree: Automatic crack detection from pavement images. *Pattern Recognition Letters*, 33(3):227–238, 2012.

[4] Hoang-Nam Nguyen, Tai-Yan Kam, and Pi-Ying Cheng. An automatic approach for accurate edge detection of concrete crack utilizing 2D geometric features of crack. *Journal of Signal Processing Systems*, 77(3):221–240, 2014.

[5] Ahmed Mahgoub Ahmed Talab, Zhangcan Huang, Fan Xi, and Liu HaiMing. Detection crack in image using Otsu method and multiple filtering in image processing techniques. *Optik*, 127(3):1030–1033, 2016.

[6] Sattar Dorafshan, Marc Maguire, and Xiaojun Qi. Automatic surface crack detection in concrete structures using OTSU thresholding and morphological operations. 2016.

[7] F´abio Celestino Pereira and Carlos Eduardo Pereira. Embedded image processing systems for automatic recognition of cracks using UAVs. *IFAC-PapersOnLine*, 48(10):16–21, 2015.

[8] S Sankarasrinivasan, E Balasubramanian, K Karthik, U Chandrasekar, and Rishi Gupta. Health monitoring of civil structures with integrated UAV and image processing system. *Procedia Computer Science*, 54:508–515, 2015.

[9] Baoxian Wang, Weigang Zhao, Po Gao, Yufeng Zhang, and Zhe Wang. Crack damage detection method via multiple visual features and efficient multi-task learning model. *Sensors*, 18(6):1796, 2018.

[10] Hyunjun Kim, Eunjong Ahn, Myoungsu Shin, and Sung-Han Sim. Crack and noncrack classification from concrete surface images using machine learning. *Structural Health Monitoring*, 18(3):725–738, 2019.

[11] Sattar Dorafshan, Robert J Thomas, Calvin Coopmans, and Marc Maguire. Deep learning neural networks for suas-assisted structural inspections: Feasibility and application. In *2018 International Conference on Unmanned Aircraft Systems (ICUAS)*, pages 874–882. IEEE, 2018.

[12] Shengyuan Li and Xuefeng Zhao. Image-based concrete crack detection using convolutional neural network and exhaustive search technique. *Advances in Civil Engineering*, 2019.

[13] MM Islam and Jong-Myon Kim. Vision-based autonomous crack detection of concrete structures using a fully convolutional encoder–decoder network. *Sensors*, 19(19):4251, 2019.

[14] Sattar Dorafshan, Robert J Thomas, and Marc Maguire. Sdnet2018: An annotated image dataset for non-contact concrete crack detection using deep convolutional neural networks. *Data in brief*, 21:1664–1668, 2018.

[15] Mohamed Abou-Zeid, David W Fowler, Edward G Nawy, John H Allen, Grant T Halvorsen, Randall W Poston, James P Barlow, Will Hansen, Royce J Rhoads, Merle E Brander, et al. Control of cracking in concrete structures. *Report, ACI Committee*, 224:12–16, 2001.

[16] Robert M Haralick, Karthikeyan Shanmugam, and Its' Hak Dinstein. Textural features for image classification. *IEEE Transactions on systems, man, and cybernetics*, (6):610–621, 1973.

[17] Sattar Dorafshan, Robert J Thomas, and Marc Maguire. Benchmarking image processing algorithms for unmanned aerial system-assisted crack detection in concrete structures. *Infrastructures*, 4(2):19, 2019.

DETECTION OF BUGHOLES USING IMAGE PROCESSING TECHNIQUE IN HYBRID CONCRETE

[a] Allah Nawaz, [b] Muhammad Imran Waris, [c] Vagelis Plevris, [d] Afaq Ahmad
a: Department of Civil Engineering, University of Engineering & Technology Taxila, Pakistan, allahnawaz396@gmail.com
b: Department of Civil Engineering, University of Engineering & Technology Taxila, Pakistan, imranwaris07@gmail.com
c: Department of Civil Engineering and Energy Technology, Oslo Metropolitan University, Norway, vageli@oslomet.no
d: Department of Civil Engineering, University of Engineering & Technology Taxila, Pakistan, afaq.ahmad@uettaxila.edu.pk

Abstract- Concrete is the most widely used construction material and its strength is affected by bugholes, caused by air entrapped in concrete, which can be removed by different admixtures and heavy compaction techniques. However, in this study waste material like silica fume (SF) and fly ash (FA) are used to remove the bugholes without compromising the compressive strength of concrete. Image Processing (IP) technique was used not only to detect the bugholes, but also to determine the area of bugholes in hybrid concrete. 24 cylinders with six different mix ratios were cast with 0%, 15%, 25% of SF, and FA as cement replacement material in concrete. 12 of them were tested in compression and 12 of them were cut into 03 slices for images. The results show that compressive strength is increased with the increase in %age of SF and FA, while the % age of bugholes decreases with an increase in %age of SF and FA.

Keywords- Bugholes Concrete, Compressive Strength, Fly Ash, Image Processing, Silica Fume.

1 INTRODUCTION

Concrete is one of the most frequently used building materials. Concrete is the composition of cement fine particles, sand, and coarse aggregate [1], where cement is the most costly material. Cement production and demand are increasing day by day which causes an increase in the production of CO_2 [2]. To reduce the cost of cement waste materials [3], cement replacement materials like silica fumes (SF), fly ash (FA), and GGBS is used to produce hybrid concrete mixes having several benefits such as low production cost, reduction in CO_2, increase environmental sustainability, and long term performance [4, 5]. Fly ash affects the compressive strength and workability of concrete. Compressive strength of concrete containing fly ash decreases at an early age then increases concerning the time at a certain level. Workability of the fly ash concrete was better than the one of simple mix concrete [6]. Toutanji et al. [7] studied the influence of silica fumes on the compressive strength of cement paste and mortar. The results of their study showed the compressive strength of concrete increased with an increase in silica fume usage and it depends on the bugholes on the surface of the concrete.

Image processing is the application of performing operations on image to acquire certain information on or from the image. Image digitization is one of the techniques of image processing in which an image is converted to a digital form where each digit in the image matrix is representing the intensity of color on the surface of that image. Jiangu et al. [8] worked on two-dimensional image analysis method for evaluating coarse aggregate properties and its distribution in concrete on self-consolidated concrete mixed with fly ash of class C and F and measured the aggregate area ratio (AAR) by using the least area rectangle (LAR) technique. Bugholes are the surface voids that are due to the migration of entrapped air during the pouring of concrete, which may affect the surface of the structure of concrete. Liu et al. [9] used image analysis tool MATLAB for the detection of bug holes, area ratio, and diameter of bug holes.

Several studies have been conducted in past using image processing to investigate bugholes but those mainly focus on plain concrete and smooth surface of the concrete. In this paper, a two-dimensional image processing method is used to detect bugholes and to find the percentage of bugholes on a concrete surface with SF and FA as cement replacement material. The influence of SF and FA on bugholes and compressive strength was also investigated. SF and FA were replaced by 0%, 15%, and 25% weight of cement. 24 concrete cylinders of dimension 300 mm × 150 mm were fabricated at 14 days and 28 days against water cement ratio of 0.5 and 0.6. Half of the total specimens were tested in compression and the other half were cut into three slices of each specimen. The top and bottom surfaces of the slices of the concrete specimen were photographed in a cabin. Digital images of the surfaces of slices were converted to grayscale, cropped at the center portion of the concrete surface, and thresholded in MATLAB. Bugholes on the top and bottom surface of each slice were detected and their area was also calculated. This technique can be utilized to determine bugholes presence in concrete, determine the ratio of bugholes, and can also be used to estimate the quality of concrete through the information of bugholes obtained from the images of concrete.

2 EXPERIMENTAL PROCEDURES

2.1 Specimen Preparation

Six concrete mix ratios containing 0%,15%, and 25% of fly ash of class F and silica fume were used to prepare 24 concrete cylinders with water cement ratio of 0.5 and 0.6. Two concrete cylinders from each mix ratio were cured at 14 days and 28 days. The chemical composition of the material is given in Table 14 and mix ratios of specimen preparation are given in Table 15.

Table 14-Chemical Composition of Cement, SF, and FA

Chemical composition (%)	**Cement**	**Silica fume**	**Fly ash**
Silica	22.4	83-87	56-64
Aluminium oxide	5	1.0 (max.)	27-33
Iron oxide	4.0	2.0-3.5	1-4
Calcium oxide	63.25	1.0-1.5	1-2
Loss on ignition	0.64	4-7	9.01

Table 15-Six different mix ratios against 0%, 15% and 25% of SF and FA

Name	Mix ratios	W/C	% FA	%SF	14 days	28 days
10.5MR-0%A	1:3:6	0.5	0	0	2	2
10.6MR-0%A	1:3:6	0.6	0	0	2	2
10.5MR-15%A	1:3:6	0.5	15%	15%	2	2
10.6MR-15%A	1:3:6	0.6	15%	15%	2	2
10.5MR-25%A	1:3:6	0.5	25%	25%	2	2
10.6MR-25%A	1:3:6	0.6	25%	25%	2	2

2.2 Compressive Strength

One cylinder from each mix ratio and curing age was tested in the laboratory to obtain the compressive strength of concrete. The compressive test was carried out according to ASTM C-39.

2.3 Cutting of Specimens

The remaining specimens of concrete mix having the mix ratio as of the ones tested for compression in the laboratory were cut into three pieces of equal size for photography. Before the photography and experimental process, Ultrasonic Pulse Velocity (UPV) test was performed on each sample and was found similar to each other. The top and bottom faces of each slice of a specimen are shown in Figure 13.

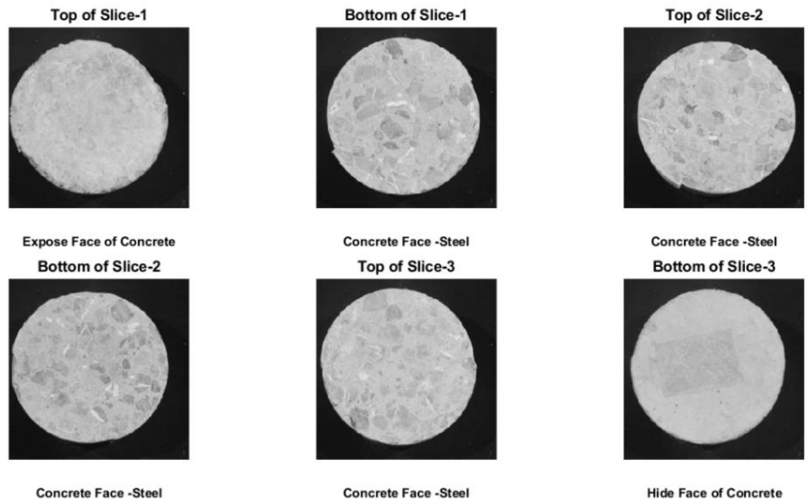


Figure 13- Top and Bottom faces of the slices of concrete cylinder

2.4 Image acquisition

A non-transparent cabin was built to form the test setup and an artificial illumination system with appropriate light intensity was installed inside the cabin. The cabin was particularly made to take photos of samples under a fixed light intensity of 2100 lux. Using daylight is not an appropriate method as it cannot maintain the same illumination for each photo. The image setup was made in a small room of dimension 2.5 m × 2.5 m. Two 30-watt LED lamps were mounted on the projector facing towards the surface of the concrete slice. Images were captured using digital camera NIKON D3300 fixed at a height of 300 mm above the concrete surface [1].

2.5 Image processing and detection of bugholes

Digital images were imported into MATLAB 2018 and converted to grayscale images using Eq. (1). The grayscale image contains shades of gray colour throughout its entire region. After conversion to grayscale, the images were centered and cropped to remove the black part of the figure which is shown in Figure 13. A pixel is the basic unit of an image with values ranging within [0, 255]. A zero value represents the black color while the 255 value denotes the white color [10]. Values in between are different shades of gray. Cropped images were thresholded with the OTSU threshold method and voids that were detected on the concrete surface are shown in Figure 14. Mask images of the cropped images, as shown in Figure 15, were also generated to calculate the area of the voids using Eq. (2).

$$Grayscale = 0.2980 * R + 0.598 * G + 110 * B \tag{1}$$

In Eq. (1), R denotes red, G denotes green and B represents the blue color. Each color value ranges within [0, 255].

$$R_b = \frac{S_b}{S} \tag{2}$$

where R_b is the ratio of bugholes, S_b is the sum of white pixels obtained from void image and S is the sum of white pixels obtained from mask image.

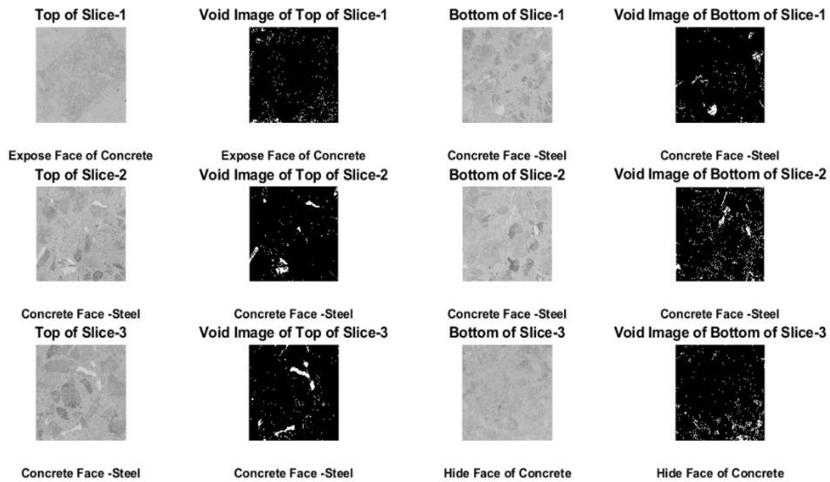


Figure 14- six face of a concrete specimen with bugholes identified images

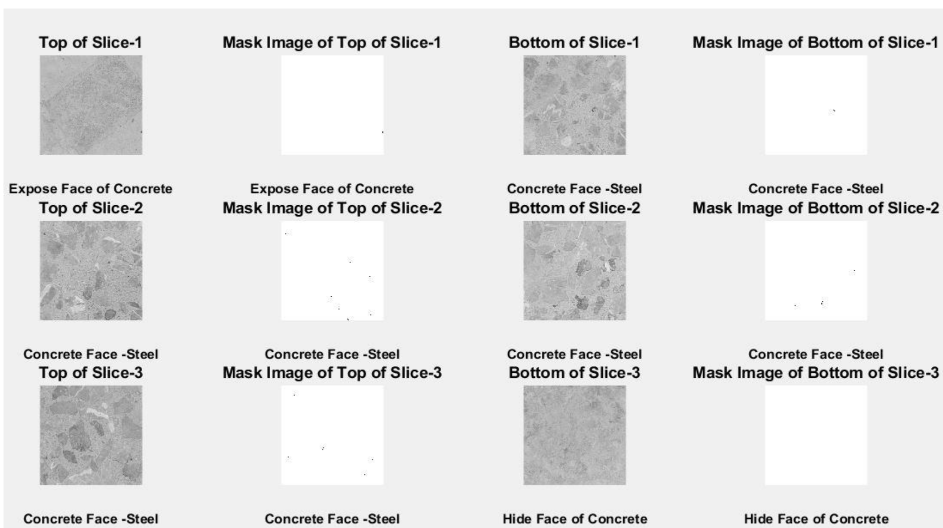


Figure 15- Mask generated images of six faces of concrete cylinder

3 RESULTS AND DISCUSSIONS

3.1 Influence of Mix Design ratios, W/C, FA and SF on compressive strength

Graphical representation of the relation between mix ratios and compressive, W/C ratio, and amount of additive is displayed in Figure 16. It can be seen that the compressive strength was lower at the age of 14 and increases at the age of 28 days. Pozzolanic activity of SF and FA produces additional calcium silicate hydrate which contributes to the strength of concrete. The increase in fc at a later age was mainly due to the pozzolanic activity of FA which starts at a later age while the pozzolanic activity of SF starts at an early age. The compressive strength plot in these graphs showed that compressive strength decreases with an increase in W/C. Compressive strength of concrete with SF and FA decreased in early age specimen but a significant increase in compressive strength was noticed in a specimen of 28 days. With 0% of SF and FA and W/C 0.6, the compressive strength of specimen is 10.20 MPa while a similar specimen with 15% of SF and FA has a compressive strength of 10.10 MPa [11]. The results showed that partial replacement of cement with silica fume had a significant effect on the compressive strength of the cylinder. The strength of concrete increases rapidly with an increase in the silica fume content [12].

3.2 Effect of FA and SF on bugholes

Figure 17 illustrated that by increasing the amount of SF and FA, there is a significant reduction in the % of bugholes[13]. SF is finer material than cement and FA particles have size almost the same as that of cement particles so they fill the micro voids in paste improving the packing of aggregates in concrete. Also, bugholes are not constant throughout the entire length of the concrete cylinder which can be noticed in the graph higher at the top face and lower at the bottom face of the slice of the concrete cylinder.

3.3 Effect of curing days on the Bugholes

From the obtained results it was seen that bugholes presence is also affected by the curing age. Specimens with 14 days curing age had a greater amount of bugholes as compared to the specimens cured at 28 days with the same specifications. As the number of bugholes decreased in 28 days samples, the compressive strength of the concrete was higher than that of samples cured at 14 days [14, 15]. Graphical representation of the effect of curing age on compressive strength can be noticed from Figure 16 and the effect of curing on bugholes can be seen Figure 17. Variation in histograms of six faces of the same specimen in Figure 18 depicts the void ratio not constant across the length of concrete specimen.

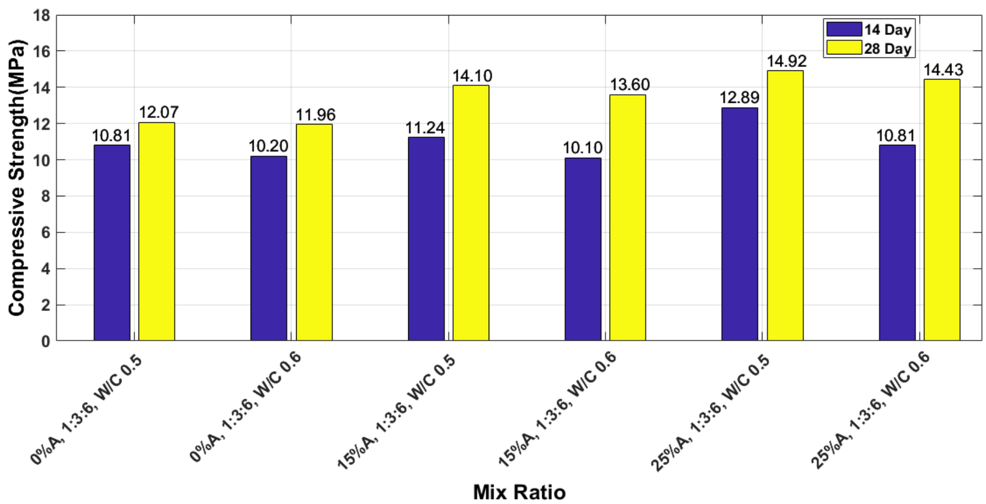


Figure 16-Compressive strength of mix ratio of concrete at 14 days and 28 days with 0%, 15%, 25% SF and FA

4 PRACTICAL IMPLICATION

Construction accepts the fact that bugholes problem is a major problem that may tend to develop crack with time so it needs to be addressed carefully. Many techniques such as surface roughness measurement techniques and pressure differential technique which are costly, require a special tool or least effective. So the image processing technique may be easily adapted in the construction industry being inexpensive, easy to use, and requires less human effort.

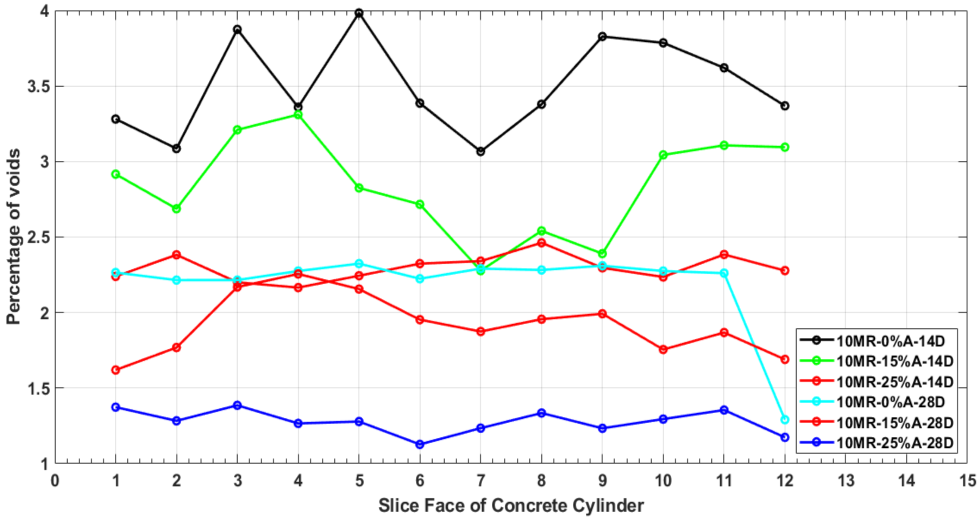


Figure 17-Percentage of the void ratio of six mix ratios of concrete with 0%, 15%, 25% SF and FA at 14 days and 28 days

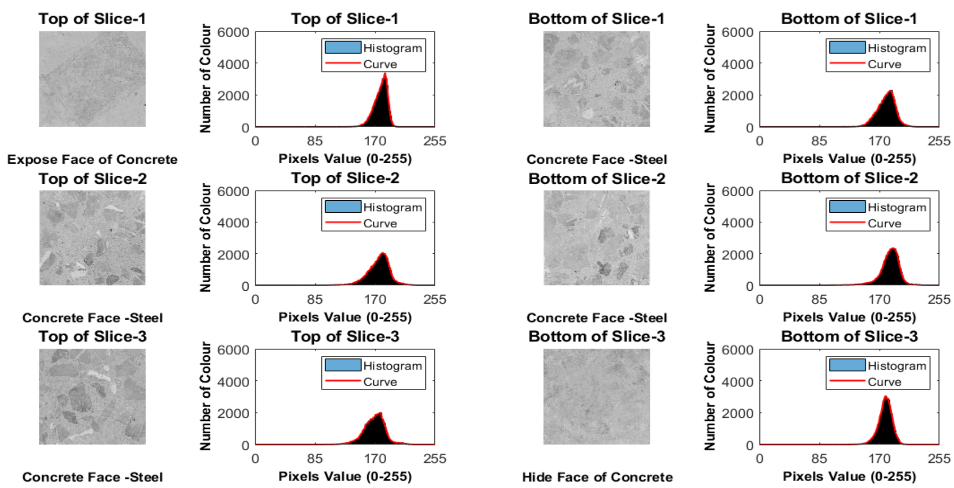


Figure 18-Histogram of six faces of the same concrete specimen showing the different number of bugholes

5 CONCLUSION

This paper mainly studies the detection of bugholes through images, the effect of SF, and FA on bugholes and the compressive strength of the specimen.

1. The image processing (IP) technique developed in this study can be used to obtain information on the existence of bugholes in concrete through images.
2. The results show that the IP technique can be utilized to detect bugholes in concrete and to determine the percentage of bugholes on the concrete surface.
3. Quality of concrete containing silica fume and fly ash can be evaluated based on information obtained from images of the concrete through this technique.
4. The compressive strength is decreased at the age of 14 days and it increases at the age of 28 days with concrete containing silica fume and fly ash

5. It is also observed that with the increase in the percentage of silica fume and fly ash concrete, bugholes initially increase and then decrease.

6 RESEARCH SIGNIFICANCE

FA and SF are eco-friendly and environmentally sustainable pozzolanic materials. The use of CRM reduces the production of CO2 and is inexpensive. The conventional way of identification of bugholes such as surveying is and inspection of high rise buildings is costly, labor-intensive, and may subject to human error. The image processing technique can detect bugholes easily through the image of the concrete surface with the help of a computer.

7 FUTURE WORK

In this phase of work, bugholes have been studied based on images of the horizontal cut surface of the concrete cylinders. In the next phase, slices of the concrete cylinders will be cut also vertically and bugholes will also be studied from the images of the vertical cut surface of the concrete specimens. Moreover, microscopic images of both surfaces will be captured to study bugholes. The focus of the study will be on (i) detection of bugholes through image processing, (ii) prediction of the percentage of bugholes through ANN, and (iii) classification of bugholes using CNN based on the diameter of bugholes.

REFERENCES

[1] G. Dogan, M. H. Arslan, and M. Ceylan, "Concrete compressive strength detection using image processing based new test method," *Measurement,* vol. 109, pp. 137-148, 2017.
[2] I. J. W. B. C. f. S. D. WBCSD and I. E. Agency, "Cement technology roadmap 2009: Carbon emissions reductions up to 2050," 2009.
[3] M. J. J. M. E. Dobiszewska, "Waste materials used in making mortar and concrete," vol. 39, no. 5-6, pp. 133-156, 2017.
[4] R. Kurad, J. D. Silvestre, J. de Brito, and H. Ahmed, "Effect of incorporation of high volume of recycled concrete aggregates and fly ash on the strength and global warming potential of concrete," *Journal of Cleaner Production,* vol. 166, pp. 485-502, 2017/11/10/ 2017.
[5] R. Bajpai, K. Choudhary, A. Srivastava, K. S. Sangwan, and M. J. J. o. C. P. Singh, "Environmental Impact Assessment of Fly Ash and Silica Fume Based Geopolymer Concrete," p. 120147, 2020.
[6] D. Ravina and P. K. Mehta, "Compressive strength of low cement/high fly ash concrete," *Cement and Concrete Research,* vol. 18, no. 4, pp. 571-583, 1988/07/01/ 1988.
[7] H. A. Toutanji, T. J. C. El-Korchi, and C. Research, "The influence of silica fume on the compressive strength of cement paste and mortar," vol. 25, no. 7, pp. 1591-1602, 1995.
[8] J. Han, K. Wang, X. Wang, P. J. J. C. Monteiro, and B. Materials, "2D image analysis method for evaluating coarse aggregate characteristic and distribution in concrete," vol. 127, pp. 30-42, 2016.
[9] B. Liu and T. Yang, "Image analysis for detection of bugholes on concrete surface," *Construction and Building Materials,* vol. 137, pp. 432-440, 2017/04/15/ 2017.
[10] G. Doğan, M. H. Arslan, and M. Ceylan, "Statistical Feature Extraction Based on an Ann Approach for Estimating the Compressive Strength of Concrete," *Neural Network World,* vol. 25, no. 3, pp. 301-318, 2015.
[11] S. Sadati, M. K. Moradllo, and M. Shekarchi, "Long-Term Performance of Silica Fume Concrete in Soil Exposure of Marine Environments," vol. 29, no. 9, p. 04017126, 2017.
[12] L. A. Qureshi, A. Janjua, and U. Muhammad, "Effect of Cement Replacement by Silica Fume on Compressive Strength of Glass Fiber Reinforced Concrete," 2018.
[13] B. Liu, T. Yang, and Y. Xie, "Factors influencing bugholes on concrete surface analyzed by image processing technology," *Construction and Building Materials,* vol. 153, pp. 897-907, 2017/10/30/ 2017.
[14] B. Liu, T. Yang, Y. J. C. Xie, and B. Materials, "Factors influencing bugholes on concrete surface analyzed by image processing technology," vol. 153, pp. 897-907, 2017.
[15] A. M. O. Wedatalla, Y. Jia, and A. A. M. Ahmed, "Curing Effects on High-Strength Concrete Properties," *Advances in Civil Engineering,* vol. 2019, p. 1683292, 2019/03/06 2019.

ASSESSMENT OF BARS LAYOUT ON THE STRENGTH OF EXISTING RC HALF-JOINT STRUCTURES USING THE PLASTIC REDISTRIBUTION METHOD

Eirini Balantina[a], Shunde Qin[b] and Furqan Qamar[c]
a: Engineer, WSP UK
b: Engineer, WSP UK
c: Corresponding Author. Principal Engineer WSP UK. Email: Furqan.Qamar@wsp.co.uk

Abstract - Half-joints structures are commonly used during the 1960s. Construction of concrete bridges using half joint was simplified due to the central spans being able to be lifted into place once the cantilevered spans were constructed. In this form of construction, the beam geometry consists of a reinforced concrete nib with a full depth section adjacent to it; the force transfer from the load point through the nib and to the full depth section is relying on the reinforcement detailing, which can vary from the as-designed drawings. Engineers who are assessing the existing half joints structures may be challenged by missing bars or reinforcement layout not compliant with the current standards. Experimental work was carried out by Desnerck et al. to identify the consequences of a series of reinforcement configurations on the capacity (load) of half joint's beams. The reference beam designed as per prevailing practice was analysed by Qamar et al. using both Strut and Tie Method (STM) and Plastic Redistribution Method (PRM), previous known as Yield Assessment Method (YAM). The aim of this paper is to compare the experimental results of the beams having missing reinforcement with analytical results using the plastic redistribution method. The effect of missing bars was not considered in the previous study. The reinforcement layout and details, covering either missing horizontal reinforced bars, missing diagonal reinforced bars or a decreased amount of shear bars, were taken from the Desnerck et al. experimental work. It was found that the resistance obtained from PRM differed with the experimental data by maximum 12%. The findings of both the PRM assessment and the empirical works suggest that the consequence of improper bars layout is evident on the strength of existing reinforced concrete half-joint structures.

***Keywords*:** Half Joint, Plastic Redistribution Method, Strut And Tie, Yield Assumption Method.

1 INTRODUCTION:

During the 1960s and 1970s several half joint structures introduced into bridge deck construction. The main advantage of this construction type is the efficient installation of a centrally supported deck, allowing a reduced construction depth by recessing the supporting corbels into the depth of the beams supported. [6]. Design of the supported spans on half-joint structures can also be standardised which facilitates a modular design approach to be used for a series of bridges. Nevertheless, reinforced concrete half-joint structures are susceptible to concrete deterioration and reinforcement corrosion due to leakage of water and chlorides ingress through the joint [2,3]. Loss of reinforcement and concrete degradation are hidden problems which cannot be easily inspected in this type of construction. In addition, another challenge which is commonly encountered by the engineers when assessing the integrity of existing half-joint structures is the lack of information regarding the as-built layout of the existing reinforcement. In many cases, there are inconsistencies between the structures and the as-designed drawings, or the reinforcement details are not compatible with the current standards. With respect to half joint bridge assessment in the UK, the DMRB standards and advice notes BD44, BA39, BA51, IAN 53 and CS 466 [7,8,9,10] provide engineers with guidance about the assessment methods and the challenge of reinforcement section loss.

Experimental work carried out by Desnerck et al. [3,4] investigated four different cases to determine the consequences of missing reinforced bars on the load failure and mode (failure) of half joint structures. The load carrying capacity of the half joints beams decreases as a result of decreasing the reinforcement amount while their failure mode is influenced. By eliminating the diagonal bars or U-bars in the nib, a failure at nib is observed, while reducing the shear reinforcement in the half joints beams results to a failure in shear across the full-depth section. The highest reduction in failure load had been observed in the beam having no diagonal reinforcement. The lowest reduction on failure load had been observed when the shear reinforcement was reduced [2].

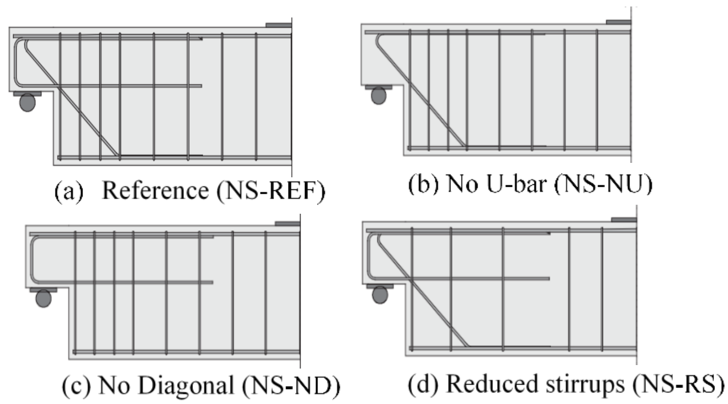


Figure 19: Reinforcement layout (Desnerck et al 2016)

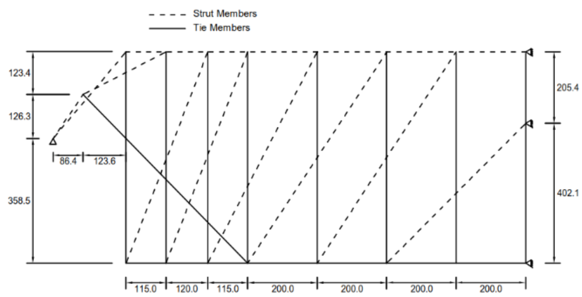
The outcome of the experimental test program by Desnerck et al. for the reference specimen (complete reinforcement arrangement) had been analysed using STM and YAM by Qamar et al.; the resistance obtained from YAM matched the experimental work within an error of 7%. The aim of this paper is to discuss the efficiency of the PRM analytical method, previous known as YAM, by comparing the experimental results with the results of the PRM for the other three specimens. In accordance with CS 466 [11], the effects of plastic redistribution may be considered to improve the conservative estimates from the strut-and-tie analysis, whilst still giving a safe estimate of resistance. The reinforcement details and layout considered including the reference specimen were taken from the experimental work by Desnerck et al. and are shown in Figure 1.

2 METHODOLGY

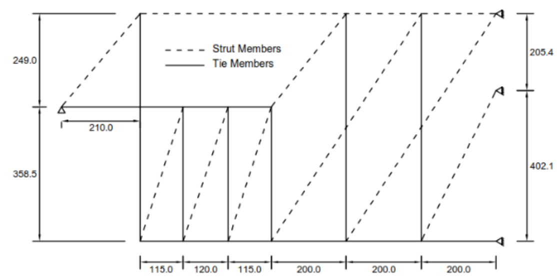
2.1 Assessment of half joint structure in accordance with PRM

The Plastic Redistribution Method (PRM) proposes a combined strut-and-tie system to estimate the resistance of the half-joint structure. The three combined strut- and-tie models utilized to evaluate the capacity of the half-joint beams with reduced reinforcement are shown in Figure 2, and they have been analysed using MIDAS Civil 2018 v2.1. The tie members, which have been assumed to be fully anchored for the current analysis, yield one by one starting with the most critical member.

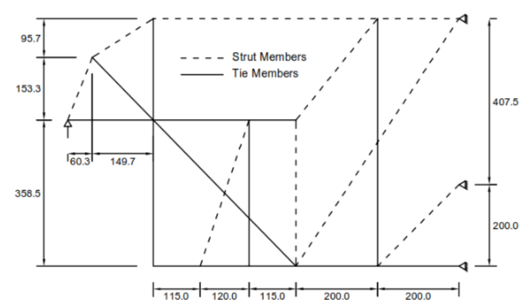
When the critical tie member starts yielding, it is replaced in the model with a pair of internal forces equal to the yield resistance of the reinforcement, applied to the relevant nodes to represent the tie in the system. The model is analysed to determine the redistributed forces in the other ties and struts. This process is followed until all tie member reach their assessment yield resistance or the model becomes unstable. No other parameters or constitutive model is considered in this method.



(a) No U bar (NS-NU)



(b) No Diagonal bar (NS-ND)



(c) Reduced stirrups (NS-RS)

Figure 20: Proposed SRM models

3 RESULTS AND DISCUSSION

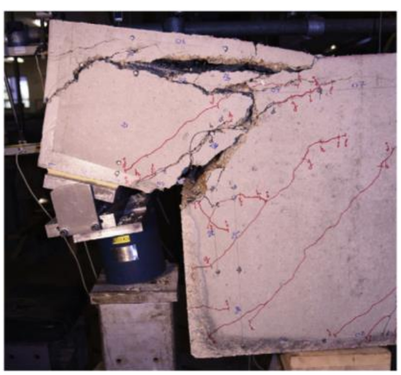
The highest predicted failure load of 431.9kN was obtained using the PRM for the reference specimen differed with the empirical data by 6.8% (Table 1). The failure of the half joint occurred when the horizontal and inclined reinforcement reached their yield resistance and caused half joint failure. The same failure mode was also observed during the empirical testing; the half-joint failure observed because of rapture of the U-bar and diagonal reinforcement at the re-entrant corner location. By reducing shear reinforcement amount, the capacity of the beam was reduced by 10.9 %, resulting in 385 kN failure load in model, which differed to the failure load from the experimental work carried out by Desnerck et al (358 kN failure load) by 8%. However, the PRM failure was occurred in the horizontal reinforcement (U-bar) and not due to a full-depth shear failure as recorded during the experiments. This may be explained due to the assumption that was made that the horizontal reinforcement was fully anchored, preventing from developing cracking in the full depth area and resulting in a theoretical failure at the corner of re-entrant.

It is also worth to note that all the partial factors were set to 1.0 for the plastic redistribution assessment. The absence of the horizontal U- bars, reduced the beam capacity, resulting in 237.6 kN failure load and reducing the half joint resistance by 45% compared to the reference specimen. The predicted failure load and empirical value differ by 12%. The highest decrement had been observed with elimination of diagonal reinforcement, resulting in 227.6 kN predicted failure load which differs to the empirical load by 7 %. The resistance of the half joint without the diagonal bars was decreased by 47% in comparison with the capacity of the reference model calculating with the PRM. The failure of the NS-ND and NS-NU specimens occurred because of diagonal and horizontal reinforcement in the corner of re-entrant, respectively, and it matches the failure mode observed during the experimental works.

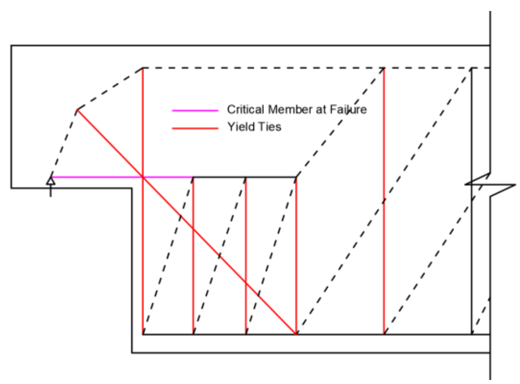
The resistance of the half joints without U-bar and diagonal reinforcement, calculated with the PRM, was slightly less as compared to the experimental results obtained by Desnerck et al. In contrast, for both the reference and with the decreased shear bars samples, the resistance of the half joint was slightly increased in comparison with the experimental work. The failure load and failure mode for all specimens for PRM and experimental work are shown in Table 1 and Figure 3.

Table 1: Half Joint Assessment Results

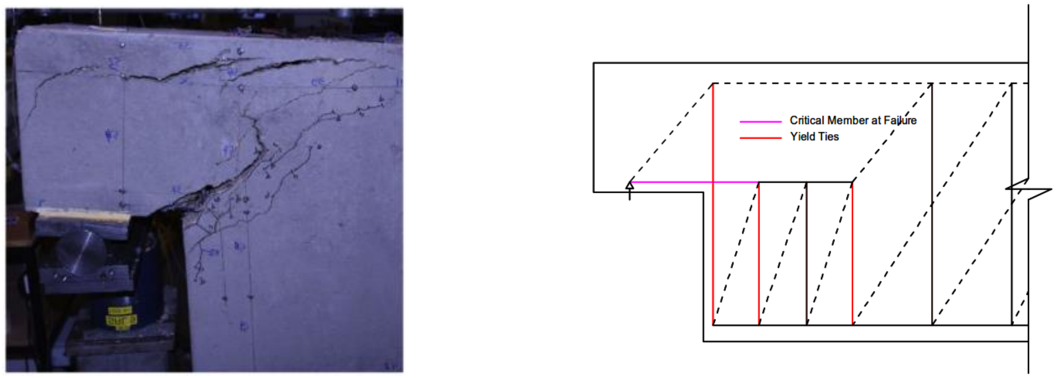
Specimen	Maximum Half Joint Capacity (kN)			Failure Mode	
	Experimental Results	SRM	Ratio (Analytical / Experimental) %	Experimental Results	SRM
NS- REF	402.3	431.9	6.8%	Due to the rupture of inclined bars and the horizontal reinforcement.	Top 2 elongated reinforcement are horizontal reinforcement and the inclined bars based on the strain analysis.
NS- ND	244.9	227.6	7%	Due to the rupture of the horizontal reinforcement in the corner of re-entrant.	The top elongated reinforcement is the horizontal reinforcement based on the strain analysis.
NS-NU	295.8	237.6	12%	Because of rupture of inclined reinforcement at re-entrant corner.	The top elongated reinforcement is the inclined reinforcement based on the strain analysis.
NS-RS	358	385	8%	Failure in shear across full-depth section of beam.	The top elongated reinforcement is the horizontal reinforcement based on the strain analysis.

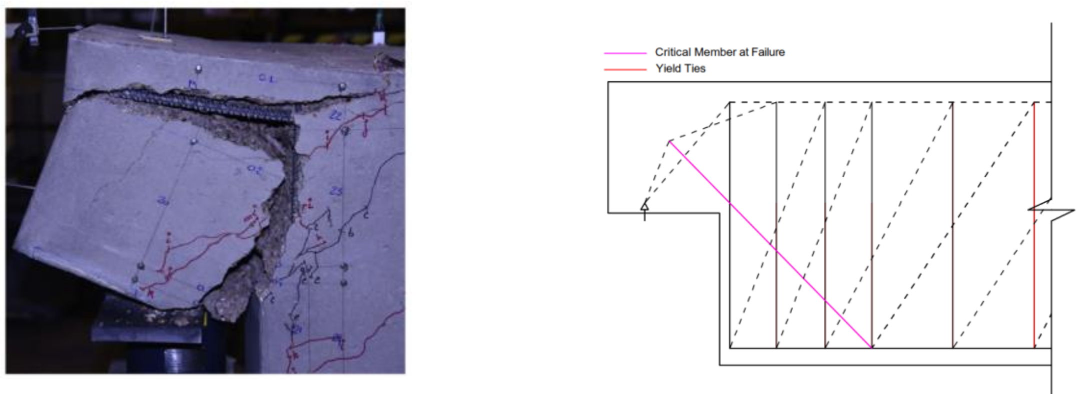


(a) NS-REF

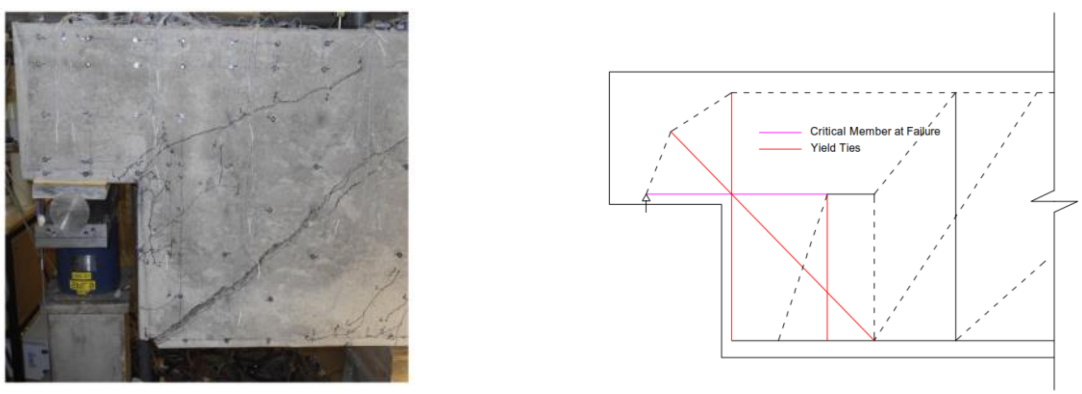


(b) No Diagonal Bar (NS-ND)





(c) No U Bar (NS-NU)



(d) Reduced stirrups (NS-RS)

Figure 21: Comparison of Failure Mode (Experimental vs SRM)

4 CONCLUSION

The findings of the empirical work carried out by Desnerck et al., which assesses the half-joints structure's response. The structures having non-compliant reinforcement arrangements were analysed in this study and compared with the analytical results using the PRM. Following are concluded from current study:

1. The highest reduction in failure load had been observed in model having no diagonal reinforcement, resulting in 227.6 kN predicted failure load and showing 47% load decrement in comparison with the capacity in base model.
2. With decreasing the shear reinforcement amount, the capacity of beam was reduced by 10.9 %
3. The predicted failure load and empirical value differ by 6.8%, 7% ,8% and 12% for base model, the model having no diagonal reinforcement, the model having reduced stirrups and the model without U-bar, respectively.
4. The failure for the reference model, the model without U-bar and with absence of diagonal reinforcement which was observed by the PRM matches the brittle failure observed at the corner of re-entrant during empirical works.

The findings of both the PRM assessment and the empirical works suggest that the consequence of improper bars layout is evident on the strength of existing reinforced concrete half-joint structures. However, by decreasing the quantity of the shear bars, the failure occurred in the horizontal reinforcement at the corner of re-entrant and not because of a full- depth shear failure as recorded during the experiments. This may be explained due to the assumption that was made that the horizontal reinforcement was fully anchored, preventing from developing cracking in the full depth area and resulting in a theoretical failure at the re-entrant corner. Additional analysis is required in order to determine the potential effect of the anchorage on the failure mode and failure load of models with non-compliant reinforcement details. Other parameters like strain and crack evaluation will be considered in the future works. The work from this study gives a better confidence in the PRM assessment and can be used in the assessment of half joint structures which are biggest problem in the construction industry. This is due to unknow reinforcement and their condition.

ACKNOWLEDGEMENTS

The authors would like to thank WSP UK Ltd as an organisation to give opportunity to carry out this study. The authors are also thankful for the proofread by Dr. Majid Ali. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES:

[1] Standards Institution. (2002) BS EN 1991-1-1:2002. Eurocode 1: Action on Strucutres. Part 1-1. *London, British Standards Institution.*

[2] Desnerck, P., Lees, J. M. & Morley, C. T. (2016) Impact of the reinforcement layout on the load capacity of reinforced concrete half-joints. *Engineering Structures*, 127 227-239.

[3] Desnerck, P., Lees, J. M. & Morley, C. T. (2017) The effect of local reinforcing bar reductions and anchorage zone cracking on the load capacity of RC half-joints. *Engineering Structures*, 152 865-877.

[4] Desnerck, P., Lees, J. M. & Morley, C. T. (2018) Strut-and-tie models for deteriorated reinforced concrete half-joints. *Engineering Structures*, 161 41-54.

[5] Departure DAS ID 20188 – Utilising the vertical links in strut-and-tie method for half-joint assessments

[6] Mattock A H. (1979) Design and behaviour of dapped end beams. *PCI Journal*

[7] The Highways Agency The assessment of concrete Highway Bridges and Structures. BD 44/15. *Highway Structures: Approval Procedures and General Design*, 3 (4)14.

[8] The Highways Agency. Assessment of reinforced concrete half-joints. BA 39/93. Highway Structures: Approval Procedures and General Design, 3(4)6.

[9] The Highways Agency The assessment of concrete structures affected by steel corrosion. BA 51/95. *Highway Structures: Approval Procedures and General Design*, 3 (4)13.

[10] The Highways Agency Concrete half-joint deck structures. IAN 53/04. *Highway Structures: Interim advice notes*.

[11] Highways England Risk management and structural assessment of concrete half-joint deck structures. CS 466. Highways Structures & Bridges Inspection & Assessment

BOND PERFORMANCE OF SUSTAINABLE REPAIRING MATERIALS WITH STEEL REINFORCEMENT

[a] Miral Fatima, [b] Hafiz Abrar Ahmad, [c] Khuram Rashid
Department of Architectural Engineering and Design,
University of Engineering and Technology, Lahore, Pakistan. Emails: a: miral.uet@gmail.com
b: abrarahmad@uet.edu.pk; c:khuram_ae@uet.edu.pk

Abstract- Owing to the notable benefits of cement concrete such as flowability, high compressive strength, temperature resistance and economy, it is being used extensively in construction industry. However, concrete structures may deteriorate due to excessive loading, aging or various environmental factors. Repairing of concrete structures is an effective approach to avoid structural collapse. Several types of repairing materials have been explored at laboratory scale as well as at industrial scale. Two recent repairing materials are; polymer cement concrete (PCC) and geopolymer concrete (GPC). Both types of repairing concrete were used in this work and their bond strength with steel reinforcement was evaluated through pullout test. Conventional concrete was also used as reference specimen and results of pull out strength were compared with it. Experimentation revealed that all three types of specimens exhibited similar bond behavior. The experimental results were also compared with the existing code. Moreover, a relationship was proposed for prediction of bond strength and it showed close correspondence with experimental observations as well as with CEB-FIP code.

Keywords- Polymer Concrete, Geopolymer Concrete, Bond Strength, Pullout Test.

1 INTRODUCTION

Concrete is a widely used structural material with its ability to resist higher compressive loads. Due to various environmental and loading effects, reinforced concrete members deteriorate resulting in shorter age as expected. This is due to the lack of implementations in repair [1]. It is important to provide an appropriate solution for the deteriorated structures, in order to fulfill their intended use and to complete their service life. Repairing of concrete structures is a suitable solution for deteriorated structure, economically as well as environmentally, than to demolish it completely [1, 2]. Usually, spalling of concrete occurs thus indicating a substantial chance of failure and ultimate collapse. Such type of structural damages cannot be repaired by externally bonded fiber reinforced polymeric sheets. So, cementitious repair is required. Different novel repair materials and techniques can be used nowadays to increase the load bearing capacity of the members. Polymer cement concrete (PCC) and geopolymer concrete (GPC) are two common materials being used as a repair material [3, 4]. These materials have high strength and better adhesion. Also, they can resist thermal and environmental effects in a better manner as compared to conventional concrete. Polymer cement mortar can be prepared by adding polymers as an admixture [5, 6]. The particles of latex, when dispersed in water, forms rigid layer with minimal voids in it. Thus, contributing to the strength of PCM [7]. Geopolymer materials are also being employed in construction industry mainly due to the current interest in sustainable development. It has received attention as an alternative to the ordinary portland cement concrete (OPC) thus reducing high carbon dioxide emissions as well as the landfill costs. High silicon or aluminum materials of geological origin or industrial by products are employed as geopolymers. Geopolymers can be prepared from either from calcined or non-calcined sources. Higher compressive strength can be achieved by incorporation of calcined sources such as metakaolin, fly ash, slag as compared to those synthesized from kaolin clay; a non-calcined source [8, 9]. Several researchers have prepared geopolymer concrete by using industrial waste products such as fly ash, slag etc. Fly ash is widely being used in the production of geopolymer mortars and concrete. Class F fly ash contains more than 70% of silicon, aluminum and iron oxides which makes it pozzolanic in nature [10]. Thus, making it favorable for the use in concrete [11]. The use of fly ash in GPC results in the formation of sodium aluminum silicate hydrate (NASH) while two hydration products are formed by using slag in geopolymer concrete i.e. NASH and calcium silicate hydrate (CSH) [12]. The use of these industrial by-products in concrete not only makes it favorable for a cleaner environment but also helps to achieve higher strength and less permeability. It has been reported that the increase in amount of geopolymer binder results in the improvement of mechanical properties as in the case of conventional concrete [12].

Reinforcing bars are provided in concrete structures to compensate for tensile stresses. Different types of reinforcing bars; steel or fiber reinforced polymer, plain or deformed, are being used in reinforced concrete (RC) structures. However, steel bars are used as the most common type of reinforcement. Concrete has the ability to maintain a strong bond with steel bars. Bond stress depends on various factors such as concrete compressive strength, development length of steel rebar, diameter of rebar, bar type etc. Bond between concrete and rebar is maintained mainly by chemical adhesion and mechanical interlock. This bond is attributed to three types of forces; adhesion forces, shear forces, friction forces. Bond strength of steel reinforcing bars with GPC has been evaluated and reported to be higher than that of steel reinforcing bars OPC [13, 14]. However, bond strength of PCC has not been reported yet.

Since, PCC and GPC are widely being used as the most suitable and sustainable repair materials and also as basic structural materials in some countries, therefore it is significant to investigate the bond strength performance of these repair materials with reinforcement. Relationships for bond stress have not been developed for PCC and GPC. The present study aims to study the bond behavior of PCC and GPC with steel reinforcement, to compare their bond behavior with OPC and to establish a relationship between bond strength and compressive strength.

2 METHODOLOGY

2.1 Materials

Ordinary concrete (OPC) was prepared in the laboratory in order to compare the results with PCC and GPC. Materials employed in the production of concrete were easily available from local market. The properties of cement, sand and aggregate are mentioned in Table 1.

Table 16-Properties of concrete constituents

Cement (Paidaar cement)		Coarse Aggregate (Sargodha crush)		Fine Aggregate (Ravi Sand)	
Specific gravity	3.15	Fineness	2.65	Fineness Modulus	2.4
Consistency	31%	Specific gravity	6.03	Specific gravity	2.61
Fineness	8%	Loose bulk density	1289 kg/m^3	Bulk density	1330 kg/m^3
Initial setting time	105min.	Rodded bulk density	1584 kg/m^3		
Final setting time	2hrs. - 5min.	Water absorption	0.99%		

Polymer cement mortar was provided by Imporient Chemicals in two-component form. Component A included cement, sand and polymeric fibers. Component B was latex to be mixed in component A in the prescribed ratio. Coarse aggregate was added in addition. PCC was cured for 28 days. Wet curing was carried out for first 7 days with jute bags and then the specimens were ambient-cured for next 21 days , as it has been reported to be the most suitable method [5]. The properties of structural repair mortar provide by the manufacturer are mentioned in APPENDIX 1. GPC was produced in the laboratory by using a combination of fly ash and slag as binders. These binders were obtained from DG cement plant in Pakistan and their properties are mentioned in Table 2. Sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) were used as alkaline activators in a ratio of 1:2.5. Sodium hydroxide was prepared in the laboratory at 12M concentration by dissolving pellets into distilled water 24 hours prior to casting. GPC was cured for 7 days under ambient conditions to get desired normal strength requirement.

Table 17 Chemical composition of binders for GPC

Material	Oxides							
	SiO_2	Al_2O_3	CaO	Fe_2O_3	MgO	K_2O	Na_2O	SO_3
Flyash	56.34	23.08	9.02	6.43	1.70	0.56	0.28	-
Slag	37.42	13.25	40.85	1.92	1.63	0.01	0.42	0.64

Reinforcement was provided by steel reinforcing bars. Deformed bars of diameter 14mm with yield strength of 453 MPa were used to determine the bond strength between three types of repairing concrete and reinforcement. This diameter of bar was selected because it is commonly available and is being used in real applications.

2.2 Preparation of specimens

Cube specimens were prepared for pullout testing and compression testing. Cube size for pullout specimens was 150 × 150 × 150 mm while that for compression testing was 100 × 100 ×100 mm.

A hole with diameter slightly greater than that of the steel bar was punched in the center of the base plate of steel cube mould, so that the steel bar can pass through it easily. A steel plate, with a hole at the center and the diameter same as that in the base plate, was clamped to the upper portion of steel cube mould in order to fix the steel bar. Steel bars were wrapped with PVC pipe to maintain the bonded length of five times diameter of bar ($5d_b$) as shown in Figure 2.

Casting and curing procedure of OPC followed the standard ASTM C192 [15]. Molds were cleaned and oiled prior to casting of specimens and steel bar was then fixed in the center of the mold. Ingredients were first weighed according to the mix design as presented in Table 1. Dry mixing of cement and half of the fine aggregate was carried first. After that; coarse aggregate, other half of fine aggregate and water was mixed for about five minutes. Concrete was poured in three layers and each layer was compacted by using vibrating table. The surface of specimens was then smoothened by steel trowel. Samples were demolded after 24 h and jute bags were used for curing. PCC was prepared by machine mixing of the two components provided by the manufacturer and coarse aggregate was added in addition. Similarly, GPC was prepared by machine mixing of binders, alkaline activators and coarse aggregate and its mix design is presented in Table 4.

Table 18-Mix design of OPC

Ingredients	Amount (kg/m^3)
Cement	368
Fine Aggregate	552
Coarse Aggregate	1105
Water	165

Table 19-Mix design of GPC

Ingredients	Amount (kg/m^3)
Flyash	384
Slag	128
Cement	128
NaOH	183 (12M)
Na_2SiO_3	457
Fine Aggregate	640
Coarse Aggregate	1280

Figure 22: Specimen Preparation

2.3 Testing of specimens

Compression test was performed on the prepared cubic specimens of 100 ×100 × 100 mm following the standard ASTM C39 [16]. Compression test was performed in order to relate bond strength with compressive strength. Specimens for compressive strength were tested at the same age as that of pullout test. Compressive load was applied on the cubes by using Universal testing machine (UTM). Pullout specimens were tested according to the standard ASTM D7913 [17]. Specimens were adjusted in the pullout assembly. Dial gage was attached to the unloading end of steel bar in order to measure relative slip. Figure 23: Testing of specimens

present the testing of the specimen.

Figure 23: Testing of specimens

3 RESULTS AND DISCUSSIONS

Compressive strength and bond strength were calculated from the experimental loads. Pullout failure mode was observed for all specimens. Bond stress-slip relationship was plotted for the specimens. Similar behavior was obtained for all three types of specimens with an increasing line with a minor slippage at first stage, then a decreasing trend and ultimately constant stress zone with a significant slip. This trend is plotted in Figure 24. Similar bond behavior of GPC has been reported in another study [18]. However, it has been reported that despite of similar bond behavior and stress-slip relationship, GPC shows slightly higher bond strength depending upon the amount of flyash or source of binders. Also, GPC can achieve relatively higher bond strength at early age due to heat curing, but for ambient curing results of GPC are quite similar to those of OPC. Bond strength for PCC has not yet been reported by any other study.

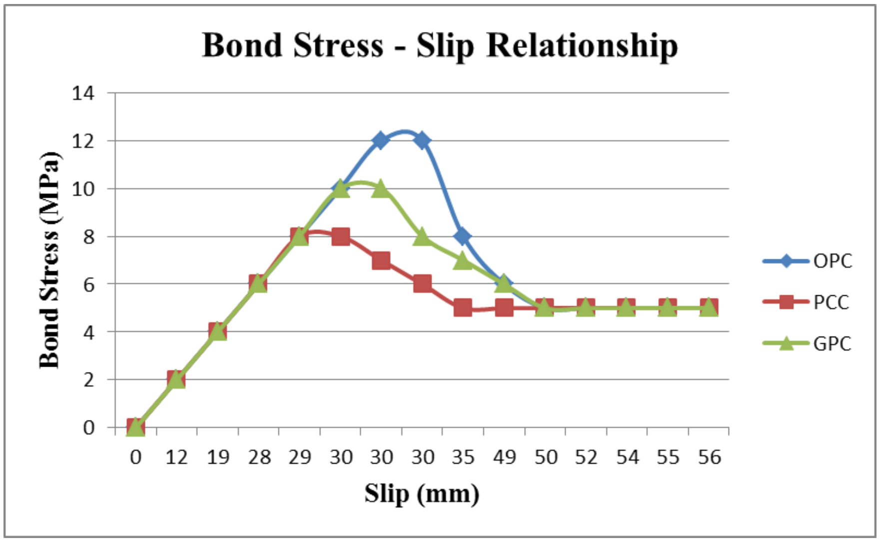


Figure 24: Bond stress - slip relationship

A relationship was developed (Eq. (A) between compressive and bond strength from the experimental results with coefficient of determination (R^2) value equal to 0.9.

$$\tau_{max} = 1.5(f_c')^{0.63} \quad \text{Eq. (A)}$$

where;
τ_{max} = Maximum bond strength (MPa)
f_c' = Compressive strength (MPa)

The obtained results were verified by using the relationship of bond stress specified by CEB-FIP 10 [19]. The relationship established by CEB-FIP Code is mentioned in Eq. (B).

$$\tau_{max} = 2.5\sqrt{f_c'} \quad \text{Eq. (B)}$$

Experimental results were in good agreement with those obtained by using the code. Upto 11% variation was observed between experimental and analytical results. Thus, PCC and GPC can be used as sustainable materials for cleaner production and already existing relationships for OPC can be used for PCC and GPC to estimate their bond strengths accurately. These repair materials require minimal maintenance and can be used effectively [3, 20].

4 CONCLUSIONS

The results of the experimentation revealed that all three types of prepared concrete exhibited similar bond behavior. This is because all materials are cementitious so the stress-slip curve showed the same trend. Thus, the analytical relations established for OPC can also be used for PCC and GPC. Moreover, the experimental results were verified by using the specified standard and a close correspondence was obtained between the relationship established in the present study through experimentation and the standard-specified relationship, thus approving the results.

5 APPENDIX

APPENDIX 1

Product Description	Repair Mortar SF is a two component fibre reinforced, cementitious polymer silica fume containing multipurpose patching and structural repair mortar.
Uses	For patching or structural repair of deteriorated concrete and mortar. It is suitable for exterior or interior, horizontal or vertical surfaces.
Advantages	Easy to mix, apply and finish Excellent adhesion to substrate Shrinkage compensated Low water absorption Non-corrosive, non-toxic
Test Standard	BS 1881 ; ASTM C 109
Technical Data:	
Form	Two components; Grey powder with Polymer Emulsion
Packing	22 kg powder: 3.0 Lit. Emulsion
Pot life	50-60 minutes at 25 $^{\circ}$C
Density	Fresh mortar: 2.0-2.1 kg/Lit.
Yield	Approx 14 litres of wet mixture
Water absorption	< 0.01 ml/m^{2}sec (BS 1881, PART 208)
Flexural strength	7-9 N/mm^2 (28 days)
Adhesion	>2.0 N/mm^2 on concrete (BS 1881, PART 207)
Temperature	Minimum 5 $^{\circ}$C Maximum 40 $^{\circ}$C
Mixing	3 minutes electric mixing (500 RPM)

ACKNOWLEDGMENT

Imporient Chemicals and DG Khan cement plants are highly acknowledged for providing polymer cement mortar and fly ash, respectively. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] N. Delatte, *Failure, distress and repair of concrete structures*: Elsevier, 2009.
[2] D. Standard and D. S. Association, *Repair of concrete structures to EN 1504*: Elsevier, 2004.
[3] G. Fahim Huseien, J. Mirza, M. Ismail, S. K. Ghoshal, and A. Abdulameer Hussein, "Geopolymer mortars as sustainable repair material: A comprehensive review," *Renewable and Sustainable Energy Reviews*, vol. 80, pp. 54-74, 2017.
[4] D. W. Fowler, "Polymers in concrete: a vision for the 21st century," *Cement and concrete composites*, vol. 21, pp. 449-452, 1999.
[5] Y. Ohama, *Handbook of polymer-modified concrete and mortars: properties and process technology*: William Andrew, 1995.

[6] Y. Ohama, "Recent progress in concrete-polymer composites," *Advanced Cement Based Materials,* vol. 5, pp. 31-40, 1997.
[7] R. Ganesh and P. Ravikumar, "Polymer modified mortar and concrete present status a review," *Journal of Mechanical and Civil Engineering,* vol. 13, pp. 89-100, 2016.
[8] J. Davidovits, "Geopolymers and geopolymeric materials," *Journal of Thermal Analysis and Calorimetry,* vol. 35, pp. 429-441, 1989.
[9] J. L. Provis and J. S. J. Van Deventer, *Geopolymers: structures, processing, properties and industrial applications*: Elsevier, 2009.
[10] A. Pourkhorshidi, M. Najimi, T. Parhizkar, F. Jafarpour, and B. Hillemeier, "Applicability of the standard specifications of ASTM C618 for evaluation of natural pozzolans," *Cement and Concrete Composites,* vol. 32, pp. 794-800, 2010.
[11] G. S. Barger, R. L. Hill, B. W. Ramme, A. Bilodeau, R. D. Hooton, D. Ravina*, et al.*, "Use of Fly Ash in Concrete," *American Concrete Institute: Farmington Hills, MI, USA*, 2003.
[12] A. Gholampour, V. D. Ho, and T. Ozbakkaloglu, "Ambient-cured geopolymer mortars prepared with waste-based sands: Mechanical and durability-related properties and microstructure," *Composites Part B: Engineering,* vol. 160, pp. 519-534, 2019.
[13] P. K. Sarker, "Bond strength of reinforcing steel embedded in fly ash-based geopolymer concrete," *Materials and Structures,* vol. 44, pp. 1021-1030, 2010.
[14] A. Hassan, M. Arif, and M. Shariq, "A Review of Properties and Behaviour of Reinforced Geopolymer Concrete Structural Elements-A Clean Technology Option for Sustainable Development," *Journal of Cleaner Production,* p. 118762, 2019.
[15] C. ASTM, "Standard practice for making and curing concrete test specimens in the laboratory," *C192/C192M,* 2007.
[16] C. ASTM, "Standard test method for compressive strength of cylindrical concrete specimens," *Chủ biên,* 2012.
[17] D. ASTM, "7913. Standard test method for bond strength of fiber-reinforced polymer matrix composite bars to concrete by pullout testing," ed: ASTM International: American Standard Test Method, 2002.
[18] A. Castel and S. J. Foster, "Bond strength between blended slag and Class F fly ash geopolymer concrete with steel reinforcement," *Cement and Concrete Research,* vol. 72, pp. 48-53, 2015.
[19] J. C. Walraven, *Model Code 2010-Final draft: Volume 1* vol. 65: fib Fédération internationale du béton, 2012.
[20] D. Van Gemert, "Synergies between polymers and cement concrete providing opportunities for sustainable construction," in *Advanced Materials Research*, 2013, pp. 12-20.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

EVALUATING THE BLEND OF NAOH AND KOH ACTIVATORS FOR ECO-FRIENDLY GEO-POLYMER CEMENT MORTAR

[a,*] Lahiba Imtiaz, [a,*]Sardar Kashif Ur Rehman, [a] Muhammad Khizar, [a] Muhammad Haseeb, [a] Haris Sajjad, [a] Sadam Munir and [a] Muhammad Sher Yar
a: Civil Engineering Department, COMSATS University Islamabad Abbottabad Campus.
*: Corresponding Author, laibaimtiaz01@gmail.com ; skashif@cuiatd.edu.pk

Abstract- Geo-polymer concrete is attaining the interest of scientific communcity as it is significantly addressing the ash disposal and CO_2 emission issues. In this study influnece of Sugarcane Bagasse ash (SCBA) was investigated on cement mortar specimens. NaOH and KOH with different molarities were used as alkali-activaots in prepartion of SCBA based geo-polymer mortar. Forty two mortar mixtures were prepared having water to binder ratio of 0.5. Test specimens were prepared with 20% change of cement weight with bagasse ash. Compression test was conducted to find the strength properties of bagasse ash based cement composite. Additionaly, water absorption test and permeable porosity test were also performed.7 days compressive strength was found less as compared with control specimens due to less geopolymerization process. Moreover, geopolymer specimens posses higher water absorption values and found depended on pH of molar solutions. In non-structural concrete member, the use of geopolymer will leads to green environment.

Keywords- SCBA, Molar Ratio, Geo-Polymerization, Naoh And KOH.

1 INTRODUCTION

Construction industry makes an important contribution in the economic growth of any country. Constant increase in demand of infrastructure is leading to its rapid growth. Nowadays, concrete is most widely used construction material due to its properties such as; high strength, durability, low cost, moldability, high-temperature resistance and low or no maintenance requirement and versatility. Consumption of concrete around the globe was around four million Metric tons in 2014 and hence; after water, it is the second most used material on earth [19]. Production of concrete imparts detrimental effects on the environment because of carbon dioxide (CO_2) emission, nitrogen oxides and sulphur oxides due to excessive use of OPC. Studies reveal that manufacturing of cement emits an almost equal quantity of carbon dioxide into the atmosphere [1].

Sugarcane Bagasse ash (SCBA) is the alternative supplementary cementitious material that can be used as a mineral admixture in concrete and mortar due to presence of huge amount of amorphous silica. It is a combustion by product from sugar boilers and alcohol factories, and has been used to improve both durability and strength properties of concrete when replaced partially with cement [18]. Accordingly, performance of SCBA concrete, comprising of SCBA, had much improved than control concrete with regards to water permeation and compressive strength. Furthermore, efficiency of ash has been enhanced by increasing the surface area with the help of grinding [8]. Geo-polymer concrete is produced by polymerizing reactive alumina silicates; metakaolin (MK), rice husk ash (RHA), fly ash (FA) and high calcium wood ash (HCWA) with alkaline activators such as potassium hydroxide (KOH), sodium hydroxide (NaOH), potassium silicate or sodium silicate that may be temperature cured or cured at room temperature. The efficacy in producing geo-polymer concrete is greatly dependent on the activators as well as types of alumina silicate resources [3, 8, 13]. The research studies on geo-polymer concrete and alkali activation had emerged in 1950's.Glukhovsky model has been widely used for alkali activation of alumina silicates materials in past years [14, 15] . Later on, researchers have conducted experimental investigations and extended the Glukhovsky's theory on geo-polymerization process involved in geo-polymer concrete and mortar [17]. Mostly, earlier studies have been conducted on FA based geo-polymer concrete. Later, SCBA in combination with rise husk ash and with other alumina silicates were used to produce geo-polymer concrete[2].

Many recent studies have also been conducted on binary mixtures of FA-SCBA and blast furnace slag (BFS) mixed with SCBA by using alkali hydroxides and silicates mixtures mainly (Na or K) alkaline activators [7, 9]. However, as per author's best knowledge, up till now no systematic study is conducted, to access the properties of geo-polymer concrete, consisting of SCBA activated with the combination of two activators such as NaOH and KOH activators. Endorsing that idea, SCBA based geo-polymer concrete activated with a blend of NaOH and KOH is intended to be investigated in this study. Influence of molarity was also determined on compressive strength and water absorption.

2 EXPERIMENTAL PROGRAM

1.1 *Materials*

Ordinary Portland cement (OPC) as per ASTM C 150 Type I was used throughout the research work. Blaine air permeability apparatus was used to determine the fineness of cement and found to be 2670 cm^2/gm. Moreover coarse and fine aggregate was sieved and analyzed. It was noted that it fulfill the requirements as per ASTM standards. ASTM C136 – 04 [4] .Distilled water was used in this study. SCBA was acquired from open burning. It was sieved through # 50 sieve to remove both course and fine fibrous carbon particles [13]. SCBA was then subjected to grinding for 120 min to achieve its maximum pozzolanic activity [14]. Its fineness was found to be 2863 cm2/gm after grinding for 120 min.

1.2 *Specimen Designation*

GxN_ayK_b represents the geo-polymer concrete sample prepared by adding solutions of two bases i-e 'xN_ayK_b' showing 'a' percent of 'x' molar NaOH and 'b' percent of 'y' molar KOH. Table 1 shows the mix proportions and specimens designations used in this study.

Table 1: Mix proportions used for preparing

Mix	Activator to Binder Ratio (A/B)	Cement (%)	Bagasse Ash (%)	Sodium Hydroxide (NaOH) (mol)	Potassium Hydroxide (KOH) (mol)
G4Na4Kb	0.5	80	20	4	4
G4Na8Kb	0.5	80	20	4	8
G4Na12Kb	0.5	80	20	4	12
G8Na4Kb	0.5	80	20	8	4
G8Na8Kb	0.5	80	20	8	8
G8Na12Kb	0.5	80	20	8	12
G12Na4Kb	0.5	80	20	12	4
G12N8K	0.5	80	20	12	8
G12N12K	0.5	80	20	12	12

1.3 Solution preparation and their pH Test

Solutions were prepared 24 hours before the casting and their pH test was conducted to find alkalinity of different NaOH and KOH molar solutions in the environmental lab, K block.

1.4 Specimen preparation

The SCBA based geo-polymer cement paste were prepared by mixing different combination of molar solution of NaOH and KOH in mix containing cement with 20% replaced bagasse ash mix having water to binder ratio of 0.5. The prepared mix was casted in 5cm x 5cm x 5cm mortar cubes' molds and after 24 hours samples were demolded and immersed in curing tank for 7 days and 28 days. The testing involved the compression test, water absorption test and the permeable porosity test at 7 and 28 days curing stage.

1.5 Compression Test

Compressive strength test was performed to check the strength of different SCBA based geo-polymer cement paste. Standard 5cm x 5cm x5cm cubes were prepared. Testing was carried out at the age of 7 days and 28 days.

1.6 Absorption test

Performed to experimentally determine water absorption capacity for different samples of geo-polymer cement paste. This test was performed in accordance with ASTM C 642-97 [5].

3 RESULTS:

Three samples of each mixtures were prepared and tested under same experimental conditions and the average value was reported in this section. The variation of the individual result was kept at less than 5% of the average value, otherwise, the mixtures were casted again

1.7 pH Test

pH values of solutions ranges from 12.17 to 15.35. The pH test of different solution is shown in the Figure 1.

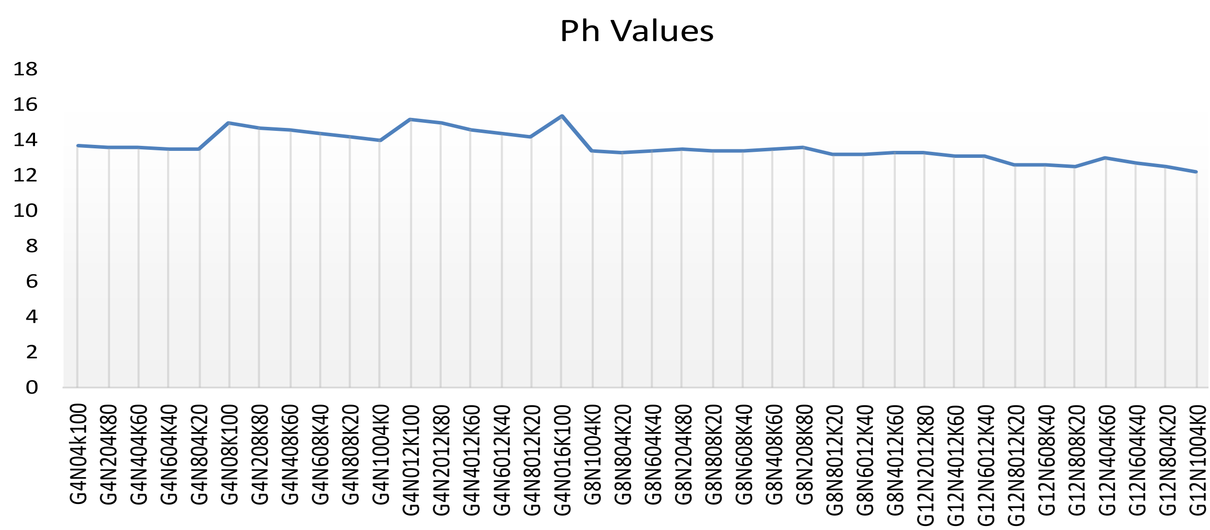


Figure 1: pH values of SCBA based geopolymer cement composites samples

1.8 Compressive strength

Strength of mortars samples that have bagasse ash was more other than the normal samples for long period. Samples having high bagasse ash content observed low compressive strength at early age i.e 7 days after casting. The compressive strength of mortar samples at early stages was less because C-S-H bond and polymerization phase was not completed. Furthermore, [20] observed that the compressive strength of geo-polymer samples decreases when cured at ambient temperature. Increase in the porosity of concrete with a large amount of SCBA incorporation resulted in the reduction of the amount of CT concrete and calcium hydroxide (from the hydration reaction). As a result, it was not sufficient for inducing the reaction with silica from the bagasse ash.

With the increase in NaOH molarity the compressive strength of alkali activated slag increases due to increase in alkalinity that results in greater formation of hydrated products. Moreover, increase in alkaline solution to drag ratio results in decreased compressive strength. Increasing the Na_2SiO_3/ NaOH increase the compressive strength and enhanced the porosity. Figure 2 shows the compressive strength values of 12 molar specimens. In addition to this, it was found that the measurement of strength and porosity and shrinkage cracks depend on type of Na^+ and K^+ ion present in activator [6].

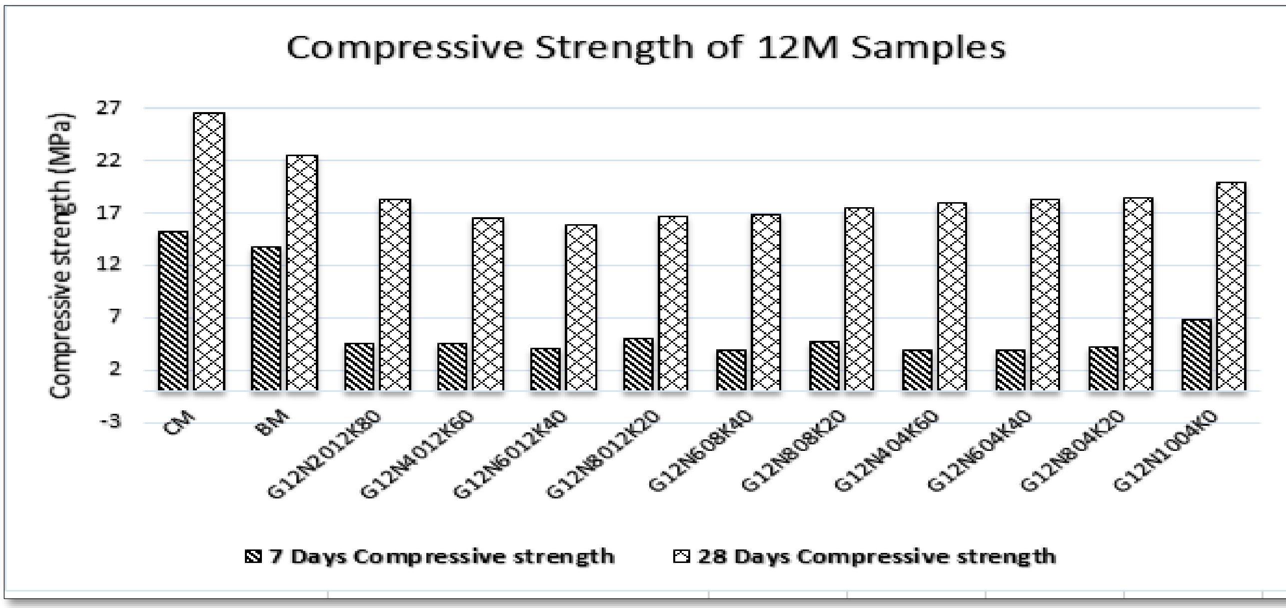


Figure 2: Compressive strength of 12M SCBA based geopolymer cement composites

1.9 Water Absorption Test

Decrease in the water absorption having high cement was change by bagasse ash. Figure 3 presents the water absorption values for various mix at 7 day and 28 days of casting. With time, reaction was time consuming, which has an important bearing on the durability of the hydrated paste; secondly, pore size distribution has shown that the reaction products are very efficient in filling up large capillary space, thus improving the strength and impermeability of the system [16]. Furthermore, with increasing molarity the temperature release become higher resulted in small cracks causing more absorption [12]. Moreover, absorption values also depend on the pH values of molar solutions [6, 10, 11].

1.10 Reactivity Index

From the results it is clear that reactivity of all the mixes, at 7 and 28 days, was lower than the CM. This was because of the fact that as the time passes more hydroxide were generated during hydration process, which was needed for continuity of pozzolanic activity. Furthermore, it can be seen that, up to 20 per cent replacement of cement with bagasse ash, met the limitation laid down by ASTM C618 for strength activity. In order to overcome this low strength issue, use of accelerator and curing at elevated temperature is recommended.

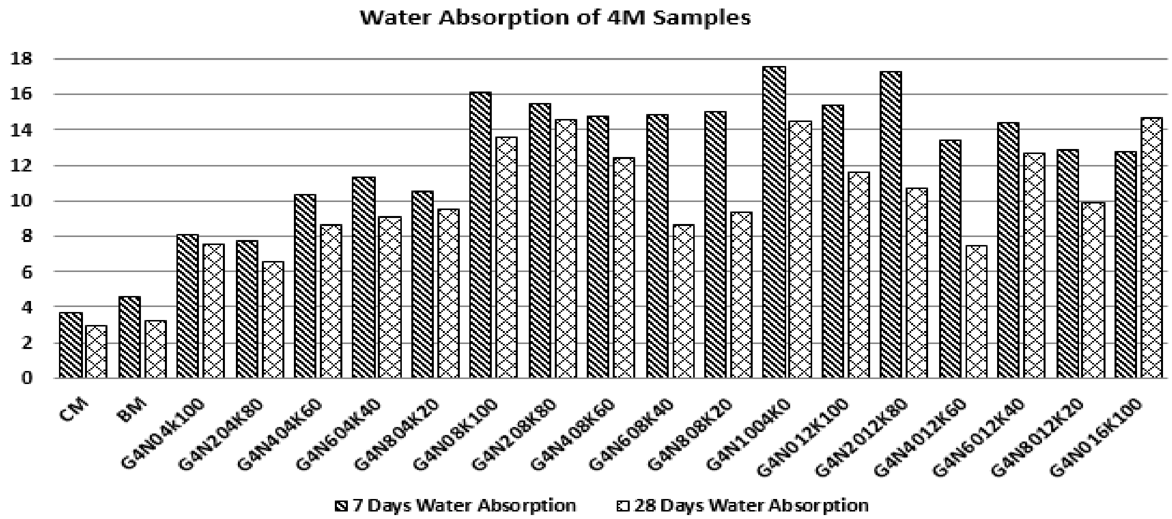


Figure 3: Water absorption of 4M SCBA based geopolymer cement composites

1.11 Application of Geopolymer concrete

The blend of NAOH and KOH activators with aluminosilicate source (e.g., metakaolin, SG, RHA, FA, HCWA etc.) results in the obtainment of geopolymer which is an amorphous material. The SCBA utilization as a source of aluminosilicate with the blend of NAOH and KOH, eventually improved the durability of geopolymers. It has excellent potential for fire resistance structures, alkali-silica reaction, and acid resistance. The utilization of bagasse ash as a source of aluminosilicate for supplementary cementing material for geopolymers through systematic processing and characterization offer a profitable and environment friendly alternative to its disposal. Moreover, the use of geopolymer leads to green environment.

4 CONCLUSION:

This study was performed to evaluate the effect of NaOH and KOH blend on preparation of eco-friendly geo-polymer concrete . Following conclusions have been drawn from the experimental work.

- Production of bagasse ash as industrial waste is quite high and likely to further increase in Pakistan. Technically and financially bagasse ash has lots of potentials to be used as pozzolan in concrete construction industry. Furthermore, its usage as construction material will also solve pollution problem. Moreover, ash is a cost-effective option without compromising on the strength parameters.
- SCBA is to be used as alumina silicate source for geo-polymer concrete after grinding for 120 min, by using blend of NaOH and KOH as activator.
- Absorption of water decreased with increase in the ash for cement replacement.
- Compressive strength of SCBA geopolymer concrete was less as compared with control specimen. However, curing at elevated temperature and use of accelerator will overcome this issue.
- Eco-friendly, low cost concrete can be produced by incorporating bagasse ash as partial replacement of cement.

ACKNOWLEDGMENT

The Authors would like to thank COMSATS University Islamabad, Abbottabad Campus for providing the research facility and funding. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] M. Abdullahi, "Effect of aggregate type on compressive strength of concrete," *International Journal of Civil and structural engineering*, vol. 2, p. 782, 2012, ISBN: (0976-4399).

[2] A. A. Aliabdo, A. E. M. A. Elmoaty, and M. A. Emam, "Factors affecting the mechanical properties of alkali activated ground granulated blast furnace slag concrete," *Construction and Building Materials*, vol. 197, pp. 339-355, 2019, ISBN: (0950-0618). doi: 10.1016/j.conbuildmat.2018.11.086

[3] L. N. Assi, E. E. Deaver, and P. Ziehl, "Effect of source and particle size distribution on the mechanical and microstructural properties of fly Ash-Based geopolymer concrete," *Construction and Building Materials*, vol. 167, pp. 372-380, 2018, ISBN: (0950-0618). doi: 10.1016/j.conbuildmat.2018.01.193

[4] C. ASTM, "ASTM-C136," vol. 04.02, 2006,

[5] C. ASTM, "ASTM C 642-06," *Standard test method for density, absorption, and voids in hardened concrete*, 2006,

[6] F. Beltzung and F. H. Wittmann, "Role of disjoining pressure in cement based materials," *Cement and Concrete Research*, vol. 35, pp. 2364-2370, 2005, ISBN: (0008-8846) doi: 10.1016/j.cemconres.2005.04.004.

[7] V. N. Castaldelli, M. M. Tashima, J. Melges, J. L. AKASAKI, J. M. M. Balbuena, M. V. B. Rosado, L. S. Martínez, and J. J. P. Bernabeu, "Preliminary estudies on the use of sugar cane bagasse ash (SCBA) in the manufacture of alkali activated binders," in *Key Engineering Materials*, 2014, pp. 689-698, ISSN: (1013-9826).

[8] P. Duxson, A. Fernández-Jiménez, J. L. Provis, G. C. Lukey, A. Palomo, and J. S. van Deventer, "Geopolymer technology: the current state of the art," *Journal of materials science*, vol. 42, pp. 2917-2933, 2007, ISBN: (0022-2461), https://doi.org/10.1007/s10853-006-0637-z.

[9] A. Hassan, M. Arif, and M. Shariq, "Use of geopolymer concrete for a cleaner and sustainable environment–A review of mechanical properties and microstructure," *Journal of cleaner production*, 2019, ISBN: (0959-6526), doi: 10.1016/j.jclepro.2019.03.051.

[10] I. Jawed and J. Skalny, "Alkalies in cement: a review: II. Effects of alkalies on hydration and performance of Portland cement," *Cement and concrete research*, vol. 8, pp. 37-51, 1978, ISBN: (0008-8846).

[11] M. C. G. Juenger and H. M. Jennings, "Effects of high alkalinity on cement pastes," *Materials Journal*, vol. 98, pp. 251-255, 2001, ISBN: (0889-325X).

[12] N. Lee, J. G. Jang, and H.-K. Lee, "Shrinkage characteristics of alkali-activated fly ash/slag paste and mortar at early ages," *Cement and Concrete Composites*, vol. 53, pp. 239-248, 2014, ISBN: (0958-9465),doi: 10.1016/j.cemconcomp.2014.07.007.

[13] C.-K. Ma, A. Z. Awang, and W. Omar, "Structural and material performance of geopolymer concrete: A review," *Construction and Building Materials*, vol. 186, pp. 90-102, 2018, ISBN: (0950-0618), doi: 10.1016/j.conbuildmat.2018.07.111.

[14] F. Matalkah, T. Salem, M. Shaafaey, and P. Soroushian, "Drying shrinkage of alkali activated binders cured at room temperature," *Construction and Building Materials*, vol. 201, pp. 563-570, 2019, ISBN: (0950-0618),doi: 10.1016/j.conbuildmat.2018.12.223.

[15] A. McCormick, A. Bell, and C. Radke, "Multinuclear NMR investigation of the formation of aluminosilicate anions," *The Journal of Physical Chemistry*, vol. 93, pp. 1741-1744, 1989, ISBN: (0022-3654),doi: 10.1021/j100342a015.

[16] A. Mehta and R. Siddique, "An overview of geopolymers derived from industrial by-products," *Construction and building materials*, vol. 127, pp. 183-198, 2016, ISBN: (0950-0618), https://doi.org/10.1016/j.conbuildmat.2016.09.136.

[17] A. Palomo and A. Fernández-Jiménez, "Alkaline activation, procedure for transforming fly ash into new materials. Part I: Applications," in *World of Coal Ash (WOCA) Conference*, 2011, pp. 1-14,

[18] S. Rukzon and P. Chindaprasirt, "Utilization of bagasse ash in high-strength concrete," *Materials & Design*, vol. 34, pp. 45-50, 2012, ISBN: (0261-3069),doi: 10.1016/j.matdes.2011.07.045.

[19] R. Silva, J. De Brito, and R. Dhir, "Prediction of the shrinkage behavior of recycled aggregate concrete: a review," *Construction and Building Materials*, vol. 77, pp. 327-339, 2015, ISBN: (0950-0618), https://doi.org/10.1016/j.conbuildmat.2014.12.102.

[20] P. R. Vora and U. V. Dave, "Parametric studies on compressive strength of geopolymer concrete," *Procedia Engineering*, vol. 51, pp. 210-219, 2013, ISBN: (1877-7058),doi: 10.1016/j.proeng.2013.01.030.

EFFECT OF ADDITION OF DIFFERENT PERCENTAGES OF BENTONITE AND FLY ASH ON COMPRESSIVE STRENGTH OF CONCRETE

[a] Engr. Asif Nazir
a: Department of Technology(Civil Division, Civil Engineering Technology),
The University of Lahore, Lahore.
Email: Asifnazir835@gmail.com

Abstract- Concrete is stone like manmade very used construction material and it is prepared by the use of cement, aggregates (Fine and Coarse aggregates) and water. Concrete is very strong construction material. It have very good strength in compressive. It is the most used material after water and its utilization is about a metric ton per annum per capita. Its remarkable properties in fresh and hardened state have raised its usage to 12 billion tons per year globally. It is a cheaper material and performs better than aluminum and steel. This research work is carried out for to investigate the effect of different percentages of Bentonite and Fly Ash on the compressive strength of concrete. In this research Calcium Bentonite and F class Fly Ash is used. Four types of samples are prepared in which M1, M2, M3 and M4 contains (0%Bentonite, 0% Fly Ash),(05%Bentonite, 05% Fly Ash), (15%Bentonite, 15% Fly Ash),(25%Bentonite, 25% Fly Ash) respectively. A 6" by 12" cylinder is used for to determine the compressive strength of concrete and total 36 cylinders were prepared in four groups according to different mix proportions. The composition mixture rate for water-cement (w/c) is 0.59 and target Compressive Strength is 2400kg/m^3.Then, the samples were cured for 7th, 14th and 28th days before testing. The result obtained showed that the concrete with additive material achieved lower compressive strength but the workability was increased. At 5% addition of Bentonite and Fly Ash maximum Compressive Strength of concrete was achieved.

Keywords- FA: Fine Aggregate , CA: Coarse Aggregate, FA: Fly Ash, BTN: Bentonite , WA: Workability

1 INTRODUCTION

1.1 General

In this research work concrete sample was made according to ASTM C-78. And this research work carried out for to determine the effect of different percentages of Bentonite and Fly Ash on workability and compressive strength of concrete. Different percentages of Bentonite and Fly Ash were replaced by cement at 5%, 15% and 25% by weight. Thirty-six samples was made and cured up to 28 days. Testing was preformed according to ASTM C-78 after 7, 14 and 28 days. Results indicate that compressive strength of concrete decrease as Bentonite and Fly Ash content increase. The increase in amount of both contents the workability increases. The optimum strength of concrete was achieved at 5% of Bentonite and Fly Ash.

1.2 Problem Statement

Cement manufacturing is a very complex procedure. A lot of Carbon dioxide (CO_2) is produced that causes global warming. As present water crisis condition in Pakistan reached at peak point, in making of cement there is lot of water is consumed. Cement is getting uneconomical day by day. This is partly the reason why the majority of the people are left with poor services. On the other hand, concrete is a porous material and concrete may contain some amount of salts and that cause efflorescence in concrete. As well as Bentonite and Fly Ash are useless material on the earth, which effect the aesthetics of natural beauty.

1.3 Objectives

- To investigate the effect of different percentages of Bentonite and Fly Ash on workability of concrete.
- To investigate the effect of different percentages of Bentonite and Fly Ash on compressive strength of concrete.
- To explore the implementation of Bentonite and Fly Ash with different construction activities.

1.4 Scope of Work

This research work will play a greater part in future to guidance of forthcoming researchers who aims to do work on Bentonite, Fly Ash and its "Effects on workability and compressive strength of normal weight concrete" in future. Also, this will help Technologist/Engineer to provide an alternative binding material of cement that will be helpful in making construction more economical as well as strong.

2 RESEARCH METHODOLOGY

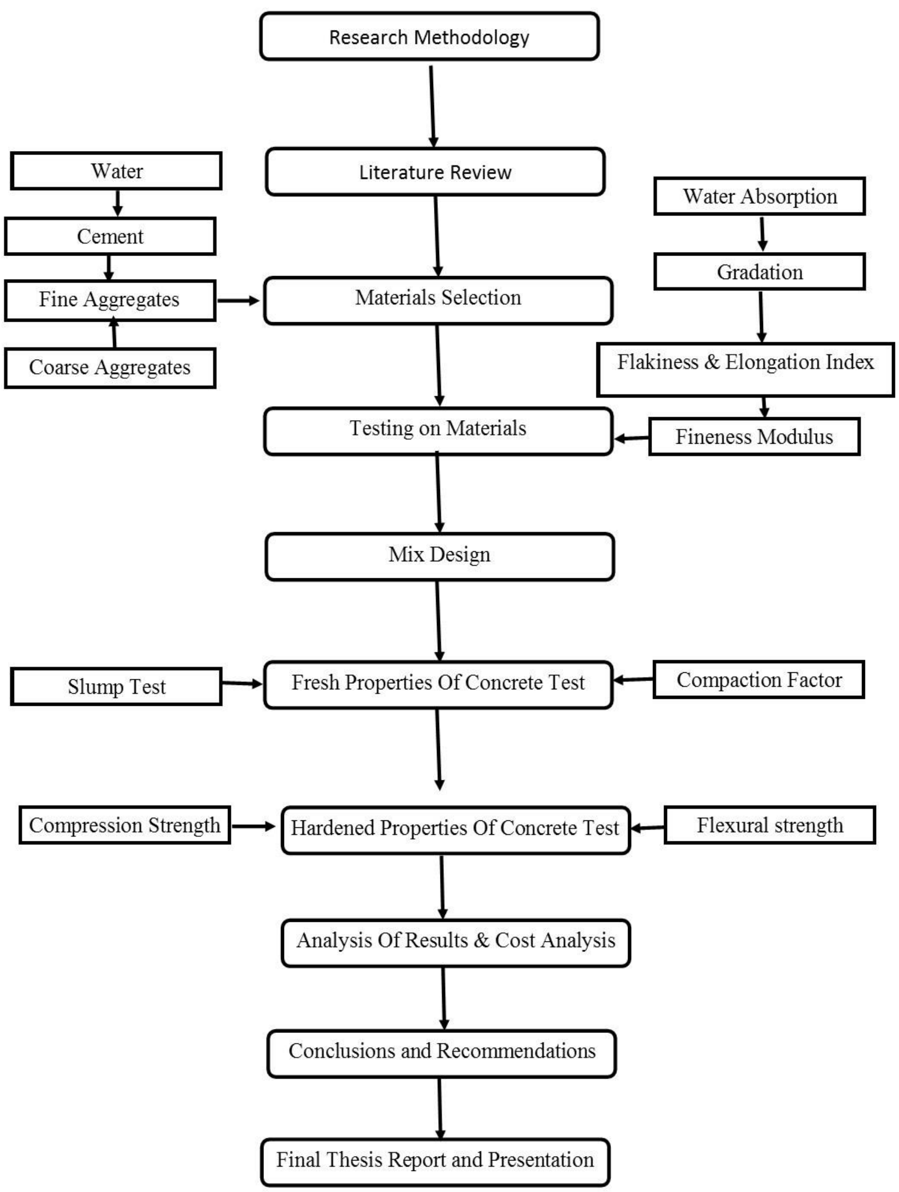


Figure 1: Research Flow Diagram

2.1 Mixing Details

By adding different percentage of Fly Ash and Bentonite 4 type of mixes was made for compression strength test:

- M1 = C (100%) + B (0%) + FA (0%) + S + A
- M2 = C (90%) + B (05%) + FA (05%) + S + A
- M3 = C (70%) + B (15%) + FA (15%) + S + A
- M4 = C (50%) + B (25%) + FA (25%) + S + A

a. Mix Design

In this research work 0.59 value used as Water/cement ratio. And for to achieve 3000 psi compressive strength 1:2:4 ratio was used.

b. Casting & Curing

Sr. No	Curing Days	M1	M2	M3	M4	Total
1	7	3	3	3	3	12
2	14	3	3	3	3	12
3	28	3	3	3	3	12
				Grand Total		36

2.2 Tests of Concrete

Following Tests was performed on Concrete:
2.2.1 Fresh Stage of Concrete

- Workability Test (Slump Test)

2.2.2 Hardened Stage of Concrete

- Compressive strength Test (Compression Test)

2.2.1.1 Slump Test of Concrete

Reference Code: *ASTM C-143/C-143 M-03*

Workability of fresh concrete is determined by slump test: The slump test was performed as per the ASTM C-143 standards guidelines. In this test the slump cone was used. Concrete filled in cone in three equal layers and compressed using 25 strokes of crimping rod. The rod was tempered having a diameter of 5/8in and length of 24 in. The slump test provides a good estimate of expected operability.

Figure 2: Slump Test

3 Results and Discussions

3.1 Compressive Strength Results

For to investigate the compressive strength of concrete cylinder specimen were used at different curing days with different proportioned of Bentonite and Fly Ash.

Compressive strength performed on cylinder as per ASTM standard test method ASTM C-39.

3.1.1 At 7 Days

Table No 02: Average Compressive Strength (MPa) at 7 Days

Sr #	Days Interval	M-1 (0%)		M-2 (5%)		M-3 (15%)		M-4 (25%)	
		MPA	**KN**	**MPA**	**KN**	**MPA**	**KN**	**MPA**	**KN**
A	**7**								
	I	11.90	210.3	9.61	169.8	6.30	112.5	3.38	59.7
	II	11.73	207.3	10.71	189.2	6.29	111.2	3.91	69.1
	III	11.86	209.7	8.34	147.5	5.57	98.4	3.04	53.7
Average		**11.83**	**209.10**	**9.55**	**168.83**	**6.05**	**107.37**	**3.44**	**60.83**

Table 2: Shows the Average Compressive Strength (MPa) of concrete at 7 Days.

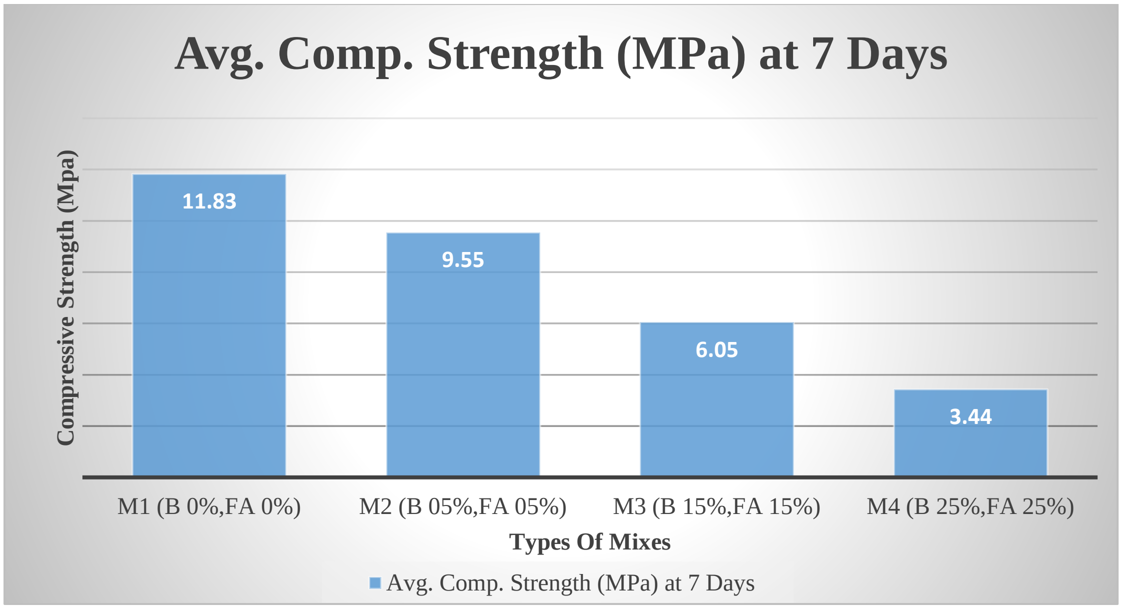


Figure 3: Average Compressive Strength (Mpa) at 7 Days.

After testing of sample at 7 days, M1 show maximum compressive strength and M4 show minimum compressive strength as detail show in table and figure above.

3.1.2 At 28 Days

Table 3: Shows the Average Compressive Strength (MPa) of concrete at 28 Days.

Sr #	**Days Interval**	**M-1 (0%)**		**M-2 (5%)**		**M-3 (15%)**		**M-4 (25%)**	
		MPA	**KN**	**MPA**	**KN**	**MPA**	**KN**	**MPA**	**KN**
C	**28**								
	I	18.03	318.6	18.07	319.4	10.07	177.9	5.92	104.6
	II	19.73	348.6	18.15	326.26	8.97	158.4	5.16	91.2
	III	18.54	327.7	17.92	316.92	9.55	168.9	4.83	85.4
Average		**18.77**	**331.63**	**18.04**	**320.86**	**9.53**	**168.40**	**5.30**	**93.73**

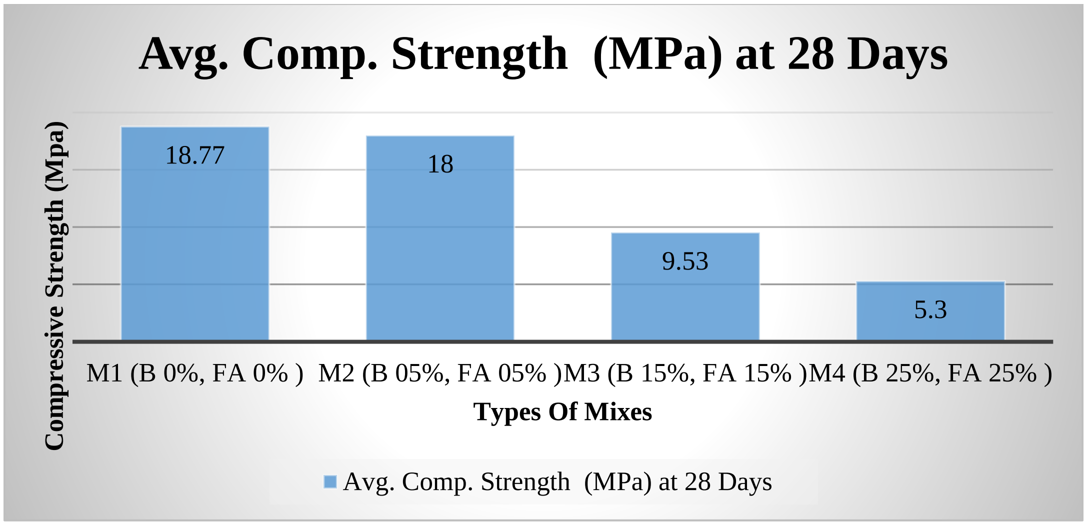


Figure 4: Average Compressive Strength (Mpa) at 28 Days.

After testing of sample at 28 days, M1 show maximum compressive strength and M4 show minimum compressive strength as detail show in table and figure above.

3.1.3 Compressive Strength Comparison at different Concrete days

Table 3: Average Compressive Strength Comparison

No of Mixes	**M-1**	**M-2**	**M-3**	**M-4**
Curing Ages	Mpa	Mpa	Mpa	Mpa
7	11.83	9.55	6.05	3.44
14	17.51	17.42	6.12	4.38
28	18.77	18.04	9.53	5.30

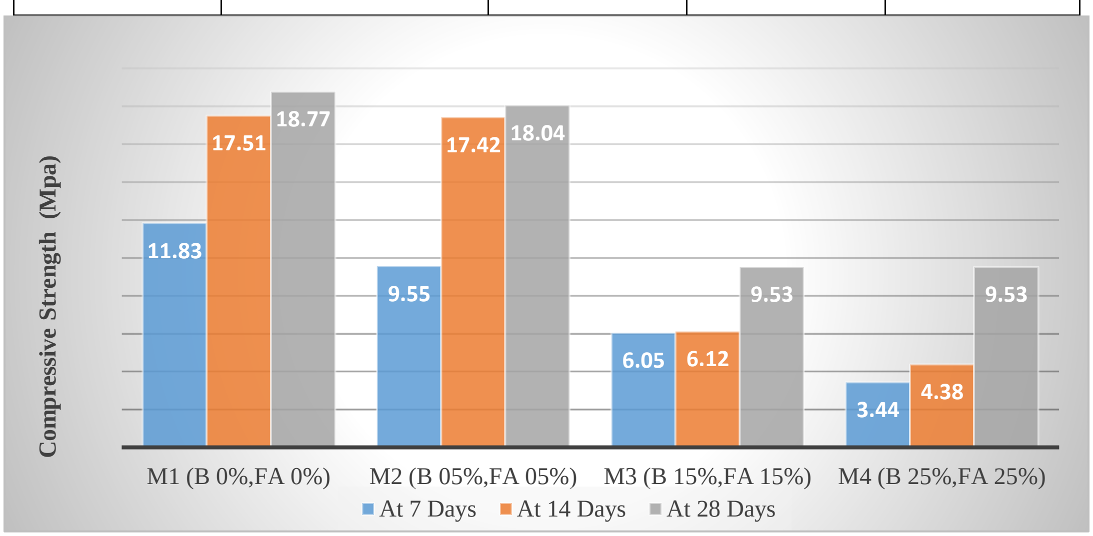


Figure 5: Compressive Strength Comparison

4 CONCLUSION & RECOMMENDATIONS

4.1 Conclusions

- Workability of concrete increase as percentage of Bentonite and Fly Ash increases;
- According to Lab results, Compressive Strength of concrete decrease by increasing the proportion of Bentonite and Fly Ash;
- At 10% of Bentonite and Fly Ash, Concrete achieved maximum compressive strength as compared to other mixes; and
- At 30% & 50% of Bentonite and Fly Ash, the compressive strength of concrete is achieved 45% and 27 % respectively of pure concrete.

4.2 Recommendations

- In this research we use the different proportions of Bentonite and Fly Ash for the scope. However, the other proportion can be used in future research;
- In this research Calcium Bentonite and F class Fly Ash is used. However, the other can be use sodium Bentonite and C class Fly Ash;
- By changing water/cement ratio, can also check the effect on compressive strength & workability of concrete;
- By changing the aggregates (fine & coarse) type, can also check the effect on compressive strength & workability of concrete; and
- By changing Cement types can also check the effect on compressive strength & workability of concrete.

REFERENCES

[1]. Shilpa, P., & Sasindran, S. (2018). Experimental Study on Concrete by Partially Replacing Cement with Calcium Bentonite and Fine Aggregate with Steel Slag.8(5), 2278-8719.
[2]. Abushad, M., & Misbah D. S. (2017). Comparative Study of Compressive Strength of Concrete with Fly Ash Replacement by Cement. 4(7),2395-0072.
[3]. Rishabh J. (2017). Effect on Compressive Strength of Concrete by Partial Replacement of Cement with Fly Ash.04,02, 315-318.
[4]. Soundarya, M. K., & Anjan, M. Incorporating Bentonite partially in place of cement-An Assessment of Strength and Durability Properties.
[5]. Aravindhraj, M., & Sapna, B. T. (2016). Influence of Bentonite in Strength and Durability of High-Performance Concrete.3(5), 3120-3124.
[6]. M. Chandrakanth, N. S. Poorna Chandra Rao., & K. Srinivasa Rao. (2016). Experimental Studies on Concrete with Bentonite as Mineral Admixture. 01(2), 2455-5703.
[7]. Amritha E.K., & Neethu, Paul. (2016). Evaluation of the Properties of Bentonite Concrete with and without Steel Fiber.07,10, ISSN 2229-5518.
[8]. P. R. Wankhede., & V. A. Fulari. (2014). Effect of Fly ASH on Properties of Concrete. 04(07), 2250-2459
[9]. Upadhyaya, S. H. A. N. T. M. U. R. T. I., & Chandak, R. (2014). Effects of fly-ash On Compressive Strength of M20 Mix Design Concrete. International Journal of Advancements in Research & Technology, ISSN, 2278-7763.
[10]. Allopi, D., & Zulu, S. (2014). Influence of high content fly ash on concrete durability.
[11]. Reddy, S. A. K., & Reddy, D. K. C. (2013). Effect of Fly Ash on Strength and Durability Parameters of Concrete. Siddhartha Institute of Engineering & Technology, Puttur, AP India.
[12]. Zhang, P., Guan, Q., & Li, Q. (2013). Mechanical properties of plastic concrete containing bentonite. Research Journal of Applied Sciences, Engineering and Technology, 5(4), 1317-1322.
[13]. Memon, S. A., Arsalan, R., Khan, S., & Lo, T. Y. (2012). Utilization of Pakistani Bentonite as partial replacement of cement in concrete. Construction and Building Materials, 30, 237-242.

[14]. Ahmad, S., Barbhuiya, S. A., Elahi, A., & Iqbal, J. (2011). Effect of Pakistani Bentonite on properties of mortar and concrete. Clay Minerals, 46(1), 85-92.
[15]. Kockal, N. U., & Ozturan, T. (2011). Durability of lightweight concretes with lightweight fly ash aggregates. Construction and Building Materials, 25(3), 1430-1438.
[16]. Nath, P., & Sarker, P. (2011). Effect of fly ash on the durability properties of high strength concrete. Procedia Engineering, 14, 1149-11
[17]. Kockal, N. U., & Ozturan, T. (2010). Effects of lightweight fly ash aggregate properties on the behavior of lightweight concretes. Journal of hazardous materials, 179(1-3), 954-965.
[18]. Mirza, J., Riaz, M., Naseer, A., Rehman, F., Khan, A. N., & Ali, Q. (2009). Pakistani bentonite in mortars and concrete as low cost construction material. Applied Clay Science, 45(4), 220-226.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

FRESH, MECHANICAL AND DURABILITY PROPERTIES OF ECO-FRIENDLY CONCRETE CONTAINING SUGARCANE BAGASSE ASH AND WOOD SAW DUST

[a]Syed Muhammad Mudassir Zia, [b]Faheem Butt
a, b: Department of Civil Engineering, University of Engineering and Technology, Taxila
a: syedmudassirzia@gmail.com
b:faheem.butt@uettaxila.edu.pk

Abstract-In this study, sugarcane bagasse ash (SCBA) and wood sawdust (WSD) has been partly replaced with the binder and fine aggregates respectively to propose optimum percentages for producing an eco-friendly concrete. The SCBA and WSD were replaced as 0%, 7%, 14% and 21%, by weight with ordinary Portland cement (OPC) and by volume with the Lawrencepur sand respectively. A total of 16 mix types were prepared to determine fresh (using slump test), hardened (using compressive, split tensile and flexural strength tests) and durability (using water absorption and acid resistance tests) properties for deciding an optimum mix. Considering the fresh and mechanical properties, the optimum values of SCBA and WSD for replacement with the OPC and sand respectively were found to be 14% and 7% respectively. The samples of blended OPC mixes prepared with WSD and SCBA showed more water absorption but better acid resistance than the control specimen.

Keywords- Eco-Friendly Concrete, Mechanical Properties, Sugarcane Bagasse Ash, Wood Saw Dust

1 INTRODUCTION

The rising production of ordinary Portland cement (OPC) has environmental issues. Researchers are looking for such kind of materials, as a partial or full replacement of OPC, which can provide ecofriendly solution. Many waste products (natural and artificial) for replacing the OPC have been investigated to produce concrete of required specifications. There is a continuous struggle and research to produce geopolymer concrete (GPC) by replacing OPC completely with other supplementary/waste binding materials. There are some natural materials, which are usually dumped as waste, have the potential to be used as a binding or fillers materials in concrete. The availability of such binding material in abundance is also posing a challenge for the researchers. The sugarcane bagasse ash (SCBA) and wood saw dust (WSD) are natural pozzolans and amongst those materials which are available in Pakistan in significant amounts and can be considered as a partial replacement of OPC and fine aggregates respectively, to produce an eco-friendly concrete.

Rajasekar et al. [1] used SCBA as a partial replacement of OPC and found 15% as an optimum value for high ultra-strength concrete. The SCBA, as a partial replacement of OPC, produced less heat during hydration and it gained additional strength[2]. The durability of concrete increased with increasing percentages of fly ash (FA) when it was replaced with OPC; however, its optimum replacement value was found to be 30% for compressive strength, after which strength decreased significantly[3]. The SCBA has also been investigated as a filler material to produce self-compacting concrete[4]. Ganesan et al. [5] concluded that 20% of SCBA replacement, burnt at 650^{o}C, was affective against attack of chlorides and achieved high early strength. Cordeiro et al. [6] found that finer SCBA was more significant to produce durable concrete than the coarser SCBA. Zareei et al.[7] replaced OPC with SCBA and found 5% as an optimum replacement value to produce lightweight and self-compacting concrete. According to Singh and Jain [8] workability was decreased and compressive strength increased for 10% replacement of SCBA with the OPC. Wood-crete members have been developed using WSD which can be used as a semi-structural member or as an insulating member [9]. Adebakin et al. [10] found that 10% of WSD was effective as a partial replacement of sand for light weight concrete. Ahmad et al.[11] concluded from their study that WSD is an effective natural byproduct to produce ecofriendly and lightweight concrete.
Pakistan, being an agricultural country, has a significant annual production of these waste/byproduct materials which can be utilized for construction. The purpose of this study is to use these natural waste/byproducts to produce an environment

friendly concrete. The present study therefore, is focused on investigation for the suitability and if so, the optimum replacement levels of SCBA and WSD with the OPC and sand respectively, to develop an equally good as the conventional concrete and an eco-friendly concrete. To achieve this, a series of mixes were prepared by varying the amount of SCBA and WSD to partially replace OPC and sand respectively in a blended OPC concrete as shown in

Table. A total of 16 mix types were designed (Table 3), comprising firstly the OPC concrete mix serving as the control mix, then the blended OPC concrete mix types with 0%, 7%, 14%, and 21% replacement levels of both SCBA and WSD, while keeping all the other ingredients the same in all the mix types. The tests are then conducted to find an optimum mix from fresh properties i.e. workability and mechanical properties viz. compressive, split tensile and flexural strengths and durability properties viz. water absorption and acid resistance tests.

2 EXPERIMENTAL PROGRAM

2.1 *Materials:*

The OPC of grade 43 from Fauji Cement Factory was used in the present study. It was made sure that cement was fresh and was stored in a secure environment to keep it safe against moisture penetration. The fineness of cement was determined through ASTMC204-18 [13]. The physical and chemical properties of the used OPC, SCBA and WSD are given in Table 1 and Table 2.

The Lawrencepur sand, passing sieve number 4, was used as fine aggregate. The fineness modulus and specific gravity of the sand as per ASTM C136 [15] and ASTM D854 [16] were determined to be 2.50 and 2.71 respectively. The Margallah crush was used as coarse aggregate, with the range of particle size from 19 mm to 9.5 mm. The water absorption of coarse aggregate was measured to be 2.5%.The SCBA utilized in this study was obtained from Layyah Sugar Mills, Layyah. The SCBA was burnt in the mill between 500ºC to 550ºC. It was then grinded in the grinding mill until 60% particles passed from Sieve No. 325. The WSD was obtained from the Timber Market, Layyah and the particles passing through 4.75 mm sieve were selected to be used in the study. The pictures of the materials used in the present study are shown in Figure 1.

Table 1: The physical properties of OPC, SCBA and WSD used in the study

Property	Specific Gravity	Unit Weight (Kg/m^3)	Passing Sieve No. 325 (%)	Fineness by Blaine (cm^2/g)
OPC	3.05	1470		3100
SCBA	2.12	610	>60	
WSD	2.15	305		

Table 2: The chemical properties of OPC and SCBA used in the study

Mix ID	CM1	BD-0.72	BD-0.14	BD-0.21	BD-7.0	BD-7.7	BD-7.14	BD-7.21	BD-14.0	BD-`14.7	BD-14.14	BD-14.21	BD-21.0	BD-21.7	BD-21.14	BD-21.21
SCBA	0%	0%	0%	0%	7%	7%	7%	7%	14%	14%	14%	14%	21%	21%	21%	21%
Saw Dust	0%	7%	14%	21%	0%	7%	14%	21%	0%	7%	14%	21%	0%	7%	14%	21%

Control Mix
[2] Blended Cement Mix with 0% SCBA and 7% WSD; Here, B stands for "sugarcane bagasse ash", D for "wood saw dust", the first numeric for % replacement level of sugarcane bagasse ash and the second numeric for % replacement level of wood saw dust respectively.

Table 3: The mix type ID's and proportions

Compound	**SiO_2**	**SO_3**	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**MnO**	**MgO**	**CaO**	**Na_2O+K_2O**	**P_2O_5**	**LOI**
OPC	19.31	2.17	0.30	5.36	3.42	0.04	2.40	62.04	1.08	0.87	2.48
SCBA	69.93	0.59		5.27	5.38			6.20	5.64	1.63	5.36

2.2 Mix proportions and samples preparation:

A total of 16 mix types were prepared by partially replacing the OPC and sand with SCBA and WSD respectively, in four different percentages i.e.0%, 07%, 14%, and 21%. The water to binder (W/B) ratio was kept constant as 0.50 for all the mixes, with a fixed binder content of 340 kg/m^3. The fine aggregates were taken as half of coarse aggregate by volume. The WSD was partially replaced with sand at 0%, 07%, 14%, and 21% by volume. Table 3 provides detail of mix types and their identities for varying percentages of SCBA and WSD.

A total of 320 samples were casted in the laboratory, comprising 96 cylinders, 96 cubes (150mm x 150mm x 150mm), 32 cubes (100mm x 100mm x 100mm), and 96 prisms. After thoroughly mixing the constituents of concrete, slump test was carried out to determine workability of fresh mix. After 24 hours of casting, samples were placed in a water tank for curing at 23°C temperature for the duration of curing. For determining compression, tensile and flexural strengths, compression test, split cylinder test and third point loading test were performed respectively. To check durability of the hardened mix specimens, water absorption and acid resistance tests were executed.

(a) (b) (c)

Mix ID	**CM[1]**	**BD-0.7[2]**	**BD-0.14**	**BD-0.21**	**BD-7.0**	**BD-7.7**	**BD-7.14**	**BD-7.21**	**BD-14.0**	**BD-`14.7**	**BD-14.14**	**BD-14.21**	**BD-21.0**	**BD-21.7**	**BD-21.14**	**BD-21.21**
SCBA	0%	0%	0%	0%	7%	7%	7%	7%	14%	14%	14%	14%	21%	21%	21%	21%
Saw Dust	0%	7%	14%	21%	0%	7%	14%	21%	0%	7%	14%	21%	0%	7%	14%	21%

Control Mix

[2] Blended Cement Mix with 0% SCBA and 7% WSD; Here, B stands for "sugarcane bagasse ash", D for "wood saw dust", the first numeric for % replacement level of sugarcane bagasse ash and the second numeric for % replacement level of wood saw dust respectively.

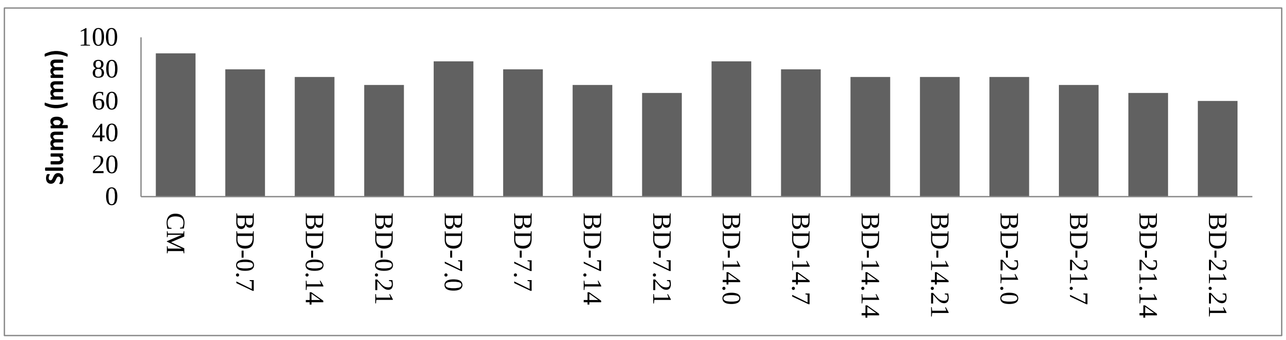
(d) €

Figure 1: The materials used in the study. (a) OPC, (b) Lawrencepur sand, (c) Coarse Aggregates, (d) SCBA, (e) WSD

3 RESULTS AND DISCUSSION

3.1 Workability:

The slump test on freshly mixed concrete was performed according to ASTM C143/C143M-05[17]. The slump test values are shown in Figure 2. It can be observed from the figure that SCBA increased slump values up to 14% replacement with

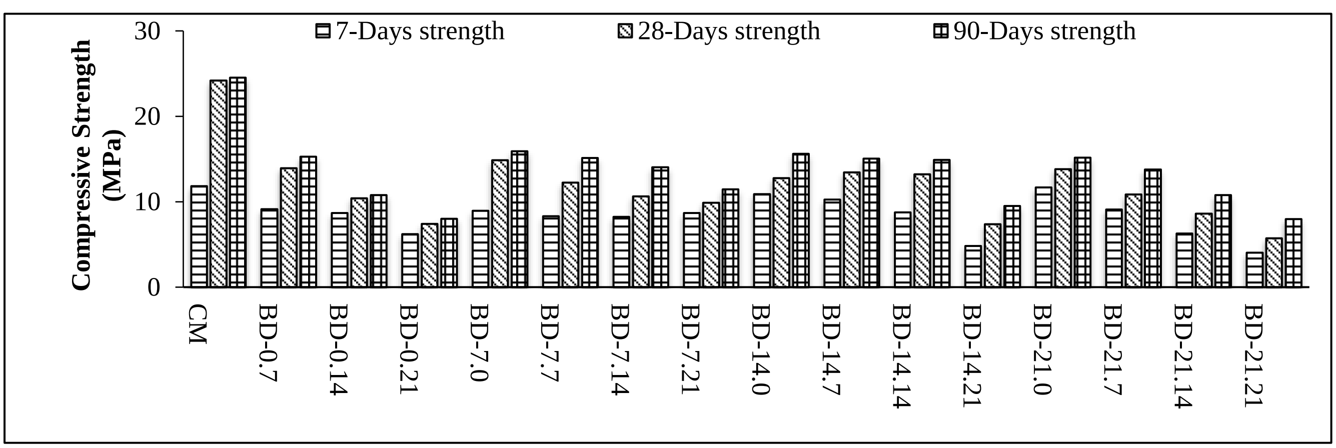


OPC. The addition of WSD has been observed to decrease the slump values for all replacement levels. The maximum value of slump for the blended OPC mix was 85 mm by BD-7.0 and BD-14.0 both; whereas lowest slump value was 60 mm depicted by BD-21.21. The optimum values, after observing the slump value trends, are for 14% SCBA and 7% WSD replacement with a slump value of 80 mm measured on BD-14.7.

Figure 2: The slump test values of mixes

3.2 Compressive Strength:

The compressive strength of 96 concrete cubes of size 150 x150 x150mm after 7, 28, and 90 days of moist curing were determined according to BS1881:Part116:1983 [18]. The compression test was carried out in 3000kN capacity machine. The compressive strength values of all mixes are shown in Figure 3. It can be observed that the partial replacement of



SCBA with OPC decreased the strength. Any increase in the strength is attributable to transformation of calcium hydrate (CH) into calcium silicate hydrate (CSH) due to the pozzolanic reaction [7]. The compressive strength in this case was found to decrease with increasing SCBA content due to low pozzolanic reaction. However, the 7 day strength was less affected than the 28 and 90 days. In the blended OPC mixes without WSD, the maximum 90 days strength was observed in BD-7.0 (15.91MPa); however a negligible decrease was observed for greater replacement levels of SCBA in BD-14.0 (15.62MPa), BD-21.0 (15.17MPa). On the other hand, the addition of WSD in the blended OPC mixes caused further decrease in the compressive strength; however, this decrease was considerably less for the blended OPC mixes with greater replacement levels of SCBA (7% and 14%) with the exception of blended OPC mixes of 21% replaced SCBA. When sand was replaced with WSD, the strength was observed to be reduced due to less formation of CSH. The optimum values, after observing the compressive strength trends, are for 14% SCBA and 7% WSD replacement with a compressive strength of 15MPa(≈2200*psi) measured on BD-14.7*.

Figure 3: The result of Compressive Strength of mixes

3.3 Splitting tensile strength:

The splitting tensile strength was determined by testing cylinders of 150 mm diameter and 300 mm height, after 7, 28, and 90 days curing, according to ASTM C496/C496M–17[19]. Figure 4 shows the result of splitting tensile strength of all the mix types. It can be observed that the tensile strength increased for blended OPC mixes without WSD, for SCBA replacement levels upto 14% i.e. BD-14.0 (2.47MPa); whereas it decreased slightly with further increase in SCBA replacement to 21% i.e. BD-21.0 (2.19MPa). With the addition of WSD to the blended OPC mixes, splitting tensile strength remains nearly the same or has a negligible decrease for 7% replacement; whereas a further increase in the replacement level to 14%, a slight decrease in the strength was observed. A considerable decrease in strength can be observed after further addition of WSD to 21% replacement level. The optimum values, after observing the split tensile strength trends, are for 14% SCBA and 7% WSD replacement with a strength of 2.37MPa (≈345*psi)*.

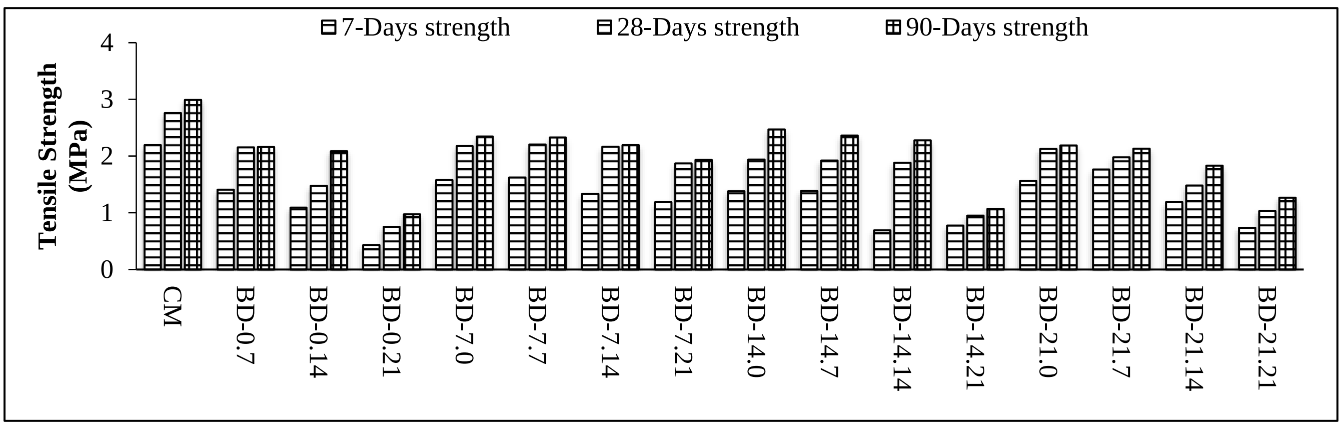
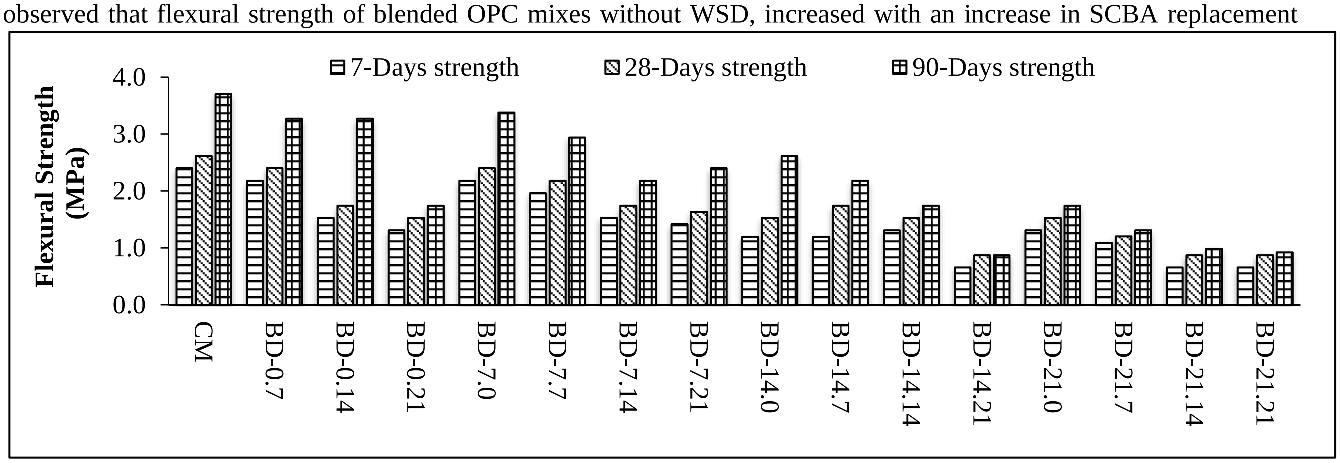


Figure 4: The result of splitting tensile strength of mixes

3.4 Flexural strength:

The flexural strength of 96 prisms of size 500 x 100 x 100 mm, after 7, 28, & 90 days of curing, were determined according to ASTM C78/C78M-18[20] using third point loading. Figure 5 shows the result of flexural strength tests. It can be observed that flexural strength of blended OPC mixes without WSD, increased with an increase in SCBA replacement



level to 7% after which it shows a decreasing trend. With the addition of WSD to the blended OPC mixes, a decrease in strength was observed with the WSD replacement level, with the exception of BD-0.7 and BD-0.14 (both shows nearly same strength after 90 days). The optimum values, after observing the flexural strength trends, are for 7% SCBA and 7% WSD replacement with a strength of 2.94MPa (≈426*psi)*.

Figure 5: The result of flexural strength of mixes

3.5 Water Absorption:

The water absorption of a specimen was determined by immersing a cube of size 100 x 100 x 100 mm in water for 24 hours[12]. After 24 hours, the wet weight of the cubic specimen is measured and placed in an oven for 2 hours at a temperature of 120°C. The dry weight is then measured and divided it by the wet weight to get percentage water absorption of the specimen. Figure 6 shows the result of water absorption of all the mix specimens.It can be observed that water absorption of blended (with SCBA) OPC mixes without WSD, increased with an increase in SCBA replacement level to 14% after which it decreased. With the addition of WSD to the blended OPC mixes, an increase in water absorption was observed for all the replacement levels. For the blended (with SCBA) OPC mixes with WSD, the least water absorption was observed in BD-14.7 (4.24%).

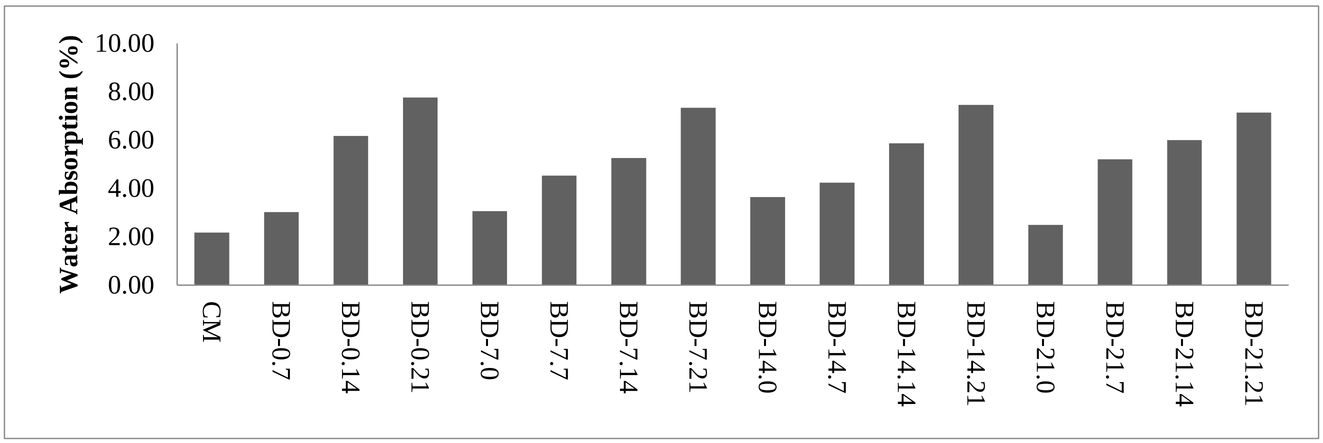
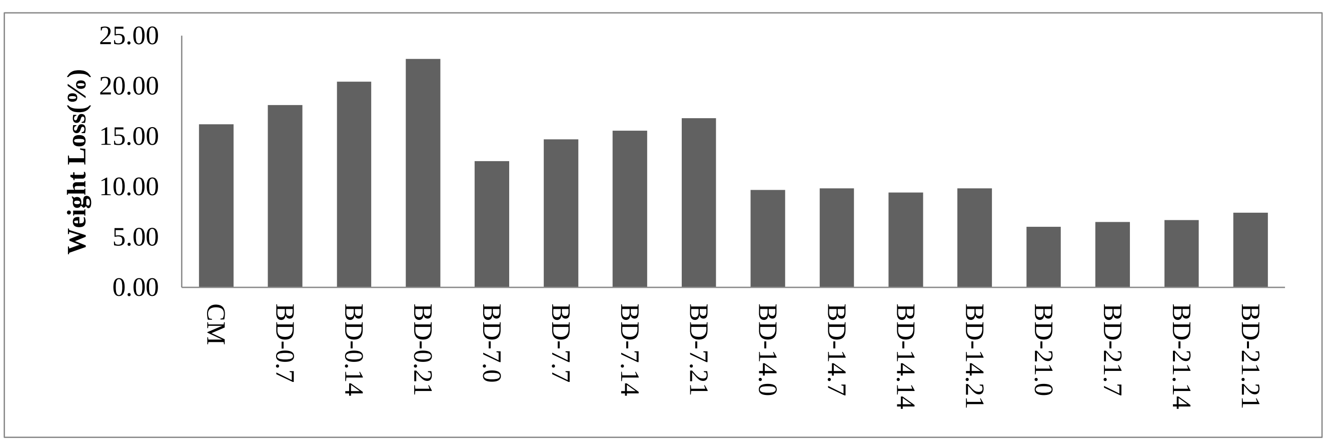


Figure 6: The result of water absorption test of mix specimens

3.6 Acid Resistance:

After completion of the curing period, a cubic specimen of size 100 x 100 x 100 mm was immersed for 60 days, in a 5% solution of sulphuric acid(H_2SO_4) [3]. The specimen was then washed with distilled water. The resistance against attack of acid was measured by finding the loss of weight. The pH value of the solution was kept constant to examine its effect on durability. Figure 7 shows the result of percent weight loss of specimen of all the mix types due to acid attack. It can be observed that replacement of both SCBA and WSD caused a noticeable decrease in the percent weight loss of specimen due to acid attack. It indicates better acid resistance of SCBA blended mixes than the OPC control mix. There is more



ettringite formation and gypsum in the control mix as compared to the blended mix with SCBA and WSD, which are major source of loss of weight, due to reaction of sulphate with C_3A and $CA(OH)_2$. [14]

Figure 7: The result of weight loss due to acid attack for different mix specimens

4 PRACTICAL IMPLEMENTATION

The acidic environment causes the concrete and mortar surface to deteriorate, eventually resulting in structure deterioration which amounts to durability issues. The better acid resistance of SCBA and WSD blended OPC mixes has provided an option for their use in such harsh environments in the form of sewerage pipes for industrial wastes and lean concrete at foundations/footing. For both uses strength requirement is significantly less than required by the reinforced concrete structural members. From this study, the optimum values of replacement levels of SCBA and WSD are 14% and 7% respectively which yielded 80mm of slump, 15MPa of compressive strength, 2.37MPa of tensile strength, 4.2% of water absorption and 9.9% of weight loss in acid attack.

5 CONCLUSION

Following conclusions can be drawn from this study:

- The SCBA replacement upto 14% with OPC increased the workability whereas an increase from 14% caused a decrease. The addition of WSD caused a decrease in the slump values for all the replacement levels. The combined effect of SCBA and WSD on workability is found more prominent, as compared to their individual effect, where slump value decreased significantly with increasing percentages of both.
- The compressive and flexural strengths slightly increased for 7% SCBA replacement after which both decreased. The WSD caused a negligible decrease with 7% replacement in compressive and tensile strengths; whereas further increase in its replacement levels caused significant decrease in both strengths. The combined effect of SCBA and WSD also caused the mechanical strength to decrease significantly.
- It can be observed from strength test results that the combination of both materials is not useful due to significant strength reduction. However, considering the fresh and mechanical properties viz. slump, compressive strength and tensile strength values, the optimum values of replacement levels of SCBA and WSD are 14% and 7% respectively which yielded 80mm of slump, 15MPa of compressive strength and 2.37MPa of tensile strength.
- The results of water absorption indicated that the blended OPC mixes with SCBA and WSD absorbs more water; however addition of SCBA resulted in better acid resistance than the OPC control mix.

REFERENCES

[1] A. Rajasekar, K. Arunachalam, M. Kottaisamy, and V. Saraswathy, "Durability characteristics of Ultra High Strength Concrete with treated sugarcane bagasse ash," *Construction Building Materials* Vol. 171, pp. 350-356, 2018.

[2] A. Bahurudeen, D. Kanraj, V. G. Dev, and M. Santhanam, "Performance evaluation of sugarcane bagasse ash blended cement in concrete," *Cement Concrete Composites,* Vol. 59, pp. 77-88, 2015.

[3] S. Aydın, H. Yazıcı, H. Yiğiter, and B. Baradan, "Sulfuric acid resistance of high-volume fly ash concrete," *Building Environment,*Vol. 42, no. 2, pp. 717-721, 2007.

[4] J. P. Moretti, S. Nunes, and A. Sales, "Self-compacting concrete incorporating sugarcane bagasse ash," *Construction building materials,* Vol. 172, pp. 635-649, 2018.

[5] K. Ganesan, K. Rajagopal, and K. Thangavel, "Evaluation of bagasse ash as supplementary cementitious material," *Cement concrete composites,* Vol. 29, no. 6, pp. 515-524, 2007.

[6] G. C. Cordeiro, R. D. Toledo Filho, L. M. Tavares, and E. d. M. R. Fairbairn, "Ultrafine grinding of sugar cane bagasse ash for application as pozzolanic admixture in concrete," *Cement concrete research,*Vol. 39, no. 2, pp. 110-115, 2009.

[7] S. A. Zareei, F. Ameri, and N. Bahrami, "Microstructure, strength, and durability of eco-friendly concretes containing sugarcane bagasse ash," *Construction Building Materials,* Vol. 184, pp. 258-268, 2018.

[8] D. Singh and S. Jain, "Experimental study of bagasse ash as a cement replacement material," *Cement and Concrete Research,* Vol. 30, pp. 1485-188, 2019.

[9] E. P. Aigbomian and M. Fan, "Development of Wood-Crete building materials from sawdust and waste paper," *Construction Building materials,* Vol. 40, pp. 361-366, 2013.

[10] I. Adebakin, A. Adeyemi, J. Adu, F. Ajayi, A. Lawal, and O. Ogunrinola, "Uses of sawdust as admixture in production of low-cost and lightweight hollow sandcrete blocks," *American journal of scientific industrial research,* Vol. 3, no. 6, pp. 458-463, 2012.

[11] W. Ahmed, R. A. Khushnood, S. A. Memon, S. Ahmad, W. L. Baloch, and M. Usman, "Effective use of sawdust for the production of eco-friendly and thermal-energy efficient normal weight and lightweight concretes with tailored fracture properties," *Journal of Cleaner Production,* Vol. 184, pp. 1016-1027, 2018.

[12] G. De Schutter and K. Audenaert, "Evaluation of water absorption of concrete as a measure for resistance against carbonation and chloride migration," *Materials structures,* Vol. 37, no. 9, p. 591, 2004.

[13] ASTMC204-18, " Standard Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus," *ASTM Int.,* 2018

[14] A. Joshaghani, "The evaluation of sugarcane bagasse ash as supplementary cementitious materials on sulphate resistance of concrete," *Concrete and Concrete structures*, Chapter No.5, 2017.

[15] ASTMC136/C136M-19, "Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates," *ASTM Int.,* 2019.

[16] ASTMD854-14, "Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer," *ASTM Int.,* 2014.

[17] ASTMC143/C143M-15a, "Standard Test Method for Slump of Hydraulic Cement Concrete," *ASTM Int.,* 2015.

[18] BS1881-116-1983, "Method of Determination of Compressive Strength of Concrete Cubes," *BSI,* 1983.

[19] ASTMC496/C496M-17, "Standard Test Method forSplitting Tensile Strength of Cylindrical ConcreteSpecimens," *ASTM Int.,* 2017.

[20] ASTMC78/C78M-18, "Standard Test Method for Flexural Strength of Concrete (Using Simple Beam withThird-Point Loading)," *ASTM Int.,* 2018.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

FRESH AND MECHANICAL PROPERTIES OF AMBIENT CURED TERNARY BLENDED GEOPOLYMER CONCRETE REINFORCED WITH STEEL FIBERS

[a] Muhammad Ibraheem, [b] Faheem Butt
[a, b] Department of Civil Engineering,
University of Engineering and Technology, Taxila
a:ibrahim.123456@yahoo.com
b: faheem.butt@uettaxila.edu.pk

Abstract- This paper focuses on development of a substitute binding material to replace Ordinary Portland cement (OPC) in conventional concreting. A total of 15 mix types (cured at ambient temperature) for the fly ash (FA) and slag (SG) based geopolymer concrete (GPC) with quarry rock dust (QRD) as a partial replacement of SG, incorporated with steel fibers (SF), were prepared and tested. A series of tests to determine the fresh and hardened properties viz. slump, compressive, split tensile and flexural strength, were carried out on the prepared samples. The workability of GPC mixes decreases with the increase of QRD content. From mechanical properties, the optimum mix obtained in this study is GPC-D0.75F which contains 50% FA, 35% SG and 15% QRD by weight and 0.75% SF by volume. The compressive, splitting tensile and flexural strengths of the optimum mix have improved significantly than their OPC concrete counterpart.

Keywords- Ambient temperature curing, geopolymer concrete, quarry rock dust, steel fibers.

1 INTRODUCTION

One of the main important materials in conventional concrete is ordinary Portland cement (OPC) and its production and demand high energy. The discharge of carbon dioxide (CO_2) during the production of cement is a major problem and forced investigators to look for substitute of binding material in concrete. Geopolymer concrete (GPC), which omits conventional cement as binder, is considered as one of the potential substitutes to cement based concrete. The use of industrial by-products such as fly ash (FA), slag (SG), rice husk ash (RHA), metakaolin (MK), palm oil fuel ash (POFA), etc. as partial and whole cement replacement in conventional and geopolymer concrete has been reported [1]–[3]. It is reported that GPC production with low calcium FA resulted in a better mechanical properties at elevated temperature curing [4] which limits its use to precast members only. However, the results are relatively less promising at ambient temperature curing conditions. The reason for this is the polymerization process which efficiently takes place at elevated temperature and leads to the formation of calcium aluminate silicate hydrate (CASH) and sodium aluminate silicate hydrate (NASH) compounds [5]. Investigations have endorsed the use of SG to achieve the encouraging outcomes at ambient curing conditions [6]. In some studies the reactivity of FA was enhanced at the ambient temperature by the addition of calcium rich materials such as SG [6], alccofine [5] etc. It has been observed that FA and SG blended geopolymer mixes showed good resistance to elevated temperature [7], sodium sulphate attack but suffered deterioration in magnesium sulphate attack [8] and exhibited increased shrinkage [9]. It is also reported in an experimental work that calcium containing materials increase the rate of geopolymerization at ambient temperature, reduce the pore sizes in mix and produce compacted composite with good mechanical properties [10], [11].

Fibers are generally incorporated in concrete to control cracking due to plastic and drying shrinkages and decrease the permeability of concrete by decreasing bleeding water. Islam et al. 2017 [12] have investigated the effect of steel fibers on mechanical properties of slag-based GPC and stated that incorporation of steel fiber improve mechanical properties especially splitting tensile and flexural strength and reduce the fresh properties.

The quarry rock dust (QRD) is a residue and calcium rich material which can be used as a partial replacement of binder or filler material in GPC. This can help in reducing the environmental and land pollution by avoiding its deposition at landfills. From the literature review, it was observed that generally QRD has been used as a partial replacement of sand in geopolymer mortar [13] and cement concrete [14], [15]. However, the studies on QRD as a partial replacement of the binder material in GPC are rather limited. This study therefore, investigates the effect of steel fibers (SF) and QRD (as a partial replacement of SG), on the fresh and mechanical properties of FA-SG based GPC cured at ambient temperature. The objective of the present study is to find an optimum mix of ternary blended GPC comprising FA, SG and QRD, reinforced with SF and cured at ambient temperature condition. To achieve this, a series of mixes were prepared by varying the amount of SF and QRD (to partially replace SG) in FA-SG based GPC as shown in Table 1. Six groups of mixes were designed as shown in Table 2, comprising firstly the OPC concrete group serving as the control mix, then GPC groups with 0%, 5%, 10%, 15%, and 20% QRD, partially replacing SG (by weight of binder), while keeping all the other ingredients the same in all the groups. Further, each group comprises three mix types with 0%, 0.75% and 1.5% (by volume of composites) SF; thus making a total of 18 mix types in the six groups. The tests are then conducted to find an optimum mix from fresh properties i.e. workability and mechanical properties viz. compressive, split tensile and flexural strengths.

2 EXPERIMENTAL PROCEDURE

For preparing a mix, all the ingredients, coarse aggregate, fine aggregates and binders (FA, SG and QRD) were dry mixed thoroughly in the mixer for 2 minutes. Prior to the mixing, aggregates were prepared to the saturated surface dry (SSD) condition. The sodium hydroxide (SH) solution was prepared one day before the application [5] and mixed with sodium silicate (SS) solution at a required ratio about 30 min before its use to improve the reactivity of solution [6]. All the ingredients of concrete were mixed in a mechanical concrete mixer (tilting drum type mixer) having capacity of 0.15 m^3. The SF was then added in dry mixture and mixing is continued for another 2 minutes, ensuring adequate fiber dispersion. The purpose of adding fibers prior to the alkaline solution was to let the fibers disperse homogeneously in the mix before it becomes too viscous. Thereafter, premixed alkaline activator solution was added gradually in the mixer and mixing lasted for another 2-3 minutes to achieve uniformity. Finally, super plasticizer (SP) and remaining water were added in the mix to achieve the required workability.

The cylinders, cubes and prisms were filled with the prepared concrete mix in three layers, compacted by a vibrator and placed at ambient temperature for 24 to 48 hours. The specimens were then demolded and kept in the sunlight for 7, 28 and 56 days for testing. Three specimens were used for any test of a mix type and the average value was reported in the results.

2.1 Materials

The OPC type-II cement conforming to ASTM C-150 [16] was used for control specimens of conventional concrete. The FA, SG and QRD in different proportions were used as a binder in the production of GPC mixtures. The low class FA is the preferred source than the high class FA because high amount of calcium interfere the polymerization process and alters the microstructure [17]. The QRD was collected from the aggregate crushing plants at Margallah hills (Taxila), and grounded using a ball mill machine at Pakistan Council of Scientific and Industrial Research (PCSIR) Peshawar. Further, it was sieved through 45µm sieve to choose the finest particles for using as a binder in the GPC production. The Figure 1 shows the pictures of the used materials in the study.

The alkaline activator solution used in this study (Figure 1) consists of SS and SH. The molarity of SH was 12M and was prepared a day before the use, by mixing 98% pure flakes of it with potable water. The SS solution was collected from local commercial manufacturer. The modulus ratio (MR) of SiO_2 to Na_2O of SS was kept in between 1.90 and 2.01.

For fine and coarse aggregates, Lawrencepur sand and Margallah crush respectively was used and procured from the locally available resources. The fineness modulus of fine aggregate was conformed to ASTM-C-136-06 [18] whereas specific gravity and water absorption was conforming to ASTM-C128-15 [19]. The Specific gravity of coarse aggregate was conforming to ASTM-C127-07 [20].

The commercially available hooked end, hard-drawn wire (steel) fibers (MasterFiber® S 65), conforming to the provisions of ASTM A820 [21], Type 1 were used. The alkaline solution is generally stickier than the water; hence its use makes the GPC mixes more viscous than the OPC concrete mix. In order to increase the workability of freshly mixed GPC, a

Naphthalene Sulphonate based super plasticizer confirming to ASTM C494 [22] was used in the present study. Different materials used in this study are shown in Figure 1.

Figure 1: Images of materials used in current study

Table 1 The mix designations based on the mix compositions of OPC and GPC mixtures

Mix ID	Mix Composition	Mix ID	Mix Composition
OPC-0F	100% cement (Control Mix)	GPC-C0F	50% FA+40% SG+10% QRD
OPC-0.75F	100% cement + 0.75% steel fibers	GPC-C0.75F	50% FA+40% SG+10% QRD+0.75% Steel Fibers
OPC-1.5F	100% cement + 1.5% steel fibers	GPC-C1.5F	50% FA+40% SG+10% QRD+1.5% Steel Fibers
GPC-A0F	50%FA+50% SG	GPC-D0F	50% FA+35% SG+15% QRD
GPC-A0.75F	50%FA+50% SG +0.75% Steel Fibers	GPC-D0.75F	50% FA+35% SG+15% QRD+0.75% Steel Fibers
GPC-A1.5F	50%FA+50% SG +1.5% Steel Fibers	GPC-D1.5F	50% FA+35% SG+15% QRD+1.5% Steel Fibers
GPC-B0F	50% FA+45% SG+5% QRD	GPC-E0F	50% FA+30% SG+20% QRD
GPC-B0.75F	50% FA+45% SG+5% QRD+0.75% Steel Fibers	GPC-E0.75F	50% FA+30% SG+20% QRD+0.75% Steel Fibers
GPC-B1.5F	50% FA+45% SG+5% QRD+1.5% Steel Fibers	GPC-E1.5F	50% FA+45% SG+5% QRD+1.5% Steel Fibers

2.2 Testing methods

The fresh and mechanical properties of OPC and GPC mixes were measured by the slump test, compressive, split tensile and flexural strength tests. To determine the workability of fresh concrete, slump cone test was performed soon after the completion of mixing procedure according to ASTM C143M-15a [23]. A universal testing machine (UTM) of 3000 kN capacity was used for testing the cubes and cylinders after 7, 28 and 56 days of casting to determine the compressive [24] and splitting tensile strengths by applying loads at a rate of 8 kN/s, according to ASTM C39/C39M-03 [25] and C496/C496M−11, respectively. The flexural strength test using prismatic specimens after 28 and 56 days of casting, under third point loading was conducted using the same UTM according to ASTM C1609 / C1609M - 19a [26].

Table. 2 The mix proportion of OPC and GPC mixtures

					Concrete mixture quantity (kg/m3)														
					Binders											CA	CA		
Group ID	**Mix No.**	**Mix ID**	**B**	**C**	**FA**	**SG**	**QRD**	**SF**	**AL/B Ratio**	**W/C Ratio**	**Molarity of SH**	**SS/SH Ratio**	**SH**	**SS**	**S**	**10 mm**	**20mm**	**SPs**	**Water**
OPC	1	OPC-0F	400	400	-	-	-	-	-	0.35	-	-	-	-	680	751	340	10	140
	2	OPC-0.75F	400	400	-	-	-	58.5	-	0.35	-	-	-	-	680	752	340	10	140
	3	OPC-1.5F	400	400	-	-	-	117	-	0.35	-	-	-	-	680	753	340	10	140
GPC-A	4	GPC-A0F	400	-	200	200	0	-	0.5	-	12	1.5	80	120	680	751	340	11	35
	5	GPC-A0.75F	400	-	200	200	0	58.5	0.5	-	12	1.5	80	120	680	752	340	18	35
	6	GPC-A1.5F	400	-	200	200	0	117	0.5	-	12	1.5	80	120	680	753	340	20	35
GPC-B	7	GPC-B0F	400	-	200	180	20	-	0.5	-	12	1.5	80	120	680	754	340	12	35
	8	GPC-B0.75F	400	-	200	180	20	58.5	0.5	-	12	1.5	80	120	680	755	340	17	35
	9	GPC-B1.5F	400	-	200	180	20	117	0.5	-	12	1.5	80	120	680	756	340	21	35
GPC-C	10	GPC-C0F	400	-	200	160	40	-	0.5	-	12	1.5	80	120	680	757	340	14	35
	11	GPC-C0.75F	400	-	200	160	40	58.5	0.5	-	12	1.5	80	120	680	758	340	20	35
	12	GPC-C1.5F	400	-	200	160	40	117	0.5	-	12	1.5	80	120	680	759	340	22	35
GPC-D	13	GPC-D0F	400	-	200	140	60	-	0.5	-	12	1.5	80	120	680	760	340	14.5	35
	14	GPC-D0.75F	400	-	200	140	60	58.5	0.5	-	12	1.5	80	120	680	761	340	21	35
	15	GPC-D1.5F	400	-	200	140	60	117	0.5	-	12	1.5	80	120	680	762	340	23	35
GPC-E	16	GPC-E0F	400	-	200	120	80	-	0.5	-	12	1.5	80	120	680	763	340	14.5	35
	17	GPC-E0.75F	400	-	200	120	80	58.5	0.5	-	12	1.5	80	120	680	764	340	22	35
	18	GPC-E1.5F	400	-	200	120	80	117	0.5	-	12	1.5	80	120	680	765	340	24	35

Note: W (Water): B (Binder); C (Cement): OPC (Ordinary portland cement); SF(Steel fibers);AL (Alkaline Solution); QRD (Quarry rock dust); SG (Ground Granulated Blast Furnace); FA (Fly ash); SH (Sodium Hydroxide); SS (Sodium Silicate); SP (Superplasticizers); S (Sand); CA (Coarse Aggregates).

3 RESULTS AND DISCUSSIONS

3.1 Workability

The workability is defined as the ease of placement and compaction of a freshly made concrete. It can be observed from the Figure 2 that workability of GPC mixes decreases with the increase of QRD content (also observed by Venkata Sairam Kumar & Sai Ram [27]) and SF fraction. The decrease in the workability can be due to shape of binder particles, higher viscosity of alkaline solution and uneven scattering of fibers. The QRD particles are angular in shape [27] than FA [28] and SG [29] particles that decrease the workability and increase the water requirement. The larger surface area of fibers absorbs more binder (cement, FA, SG, QRD) mortar around the fibers which increases the shear resistance to flow, resulting in a lower slump value. The maximum workability for GPC mixes was obtained by GPC-A0F which does not have QRD and SF. However, the addition of 10-15% QRD and 0.75% SF resulted in the relatively less workable concrete. The results of different mixtures can be observed from Figure 2

3.2 Compressive strength

It can be observed from Figure 3 that the compressive strength of GPC mixes goes on increasing by increasing the QRD replacement level up to 15% after which it decreased. The increase in compressive strength upto 15% QRD content can be due to an increased quantity of calcium containing materials which accelerates the rate of polymerization at ambient temperature (room temperature) and reduce the pore sizes. The effect of calcium rich compounds on the strength properties at ambient temperature has also been reported by other studies like Dutta and Ghosh, and Temuujin et al. [10, 11]. When amount of QRD is increased further from 15% to 20% (as in mix GPC-E0F), the GPC mix becomes too sticky (least workable) and can't be easily casted. In order to make it workable, extra water or super plasticizers was added during mixing procedure which ultimately resulted in reduced compressive strength. The maximum strength was obtained by GPC-D0.75F with 15% QRD by weight of binder and 0.75% SF by volume. The compressive strength of this GPC mix is 21% higher than the corresponding fiber reinforced OPC control mix.

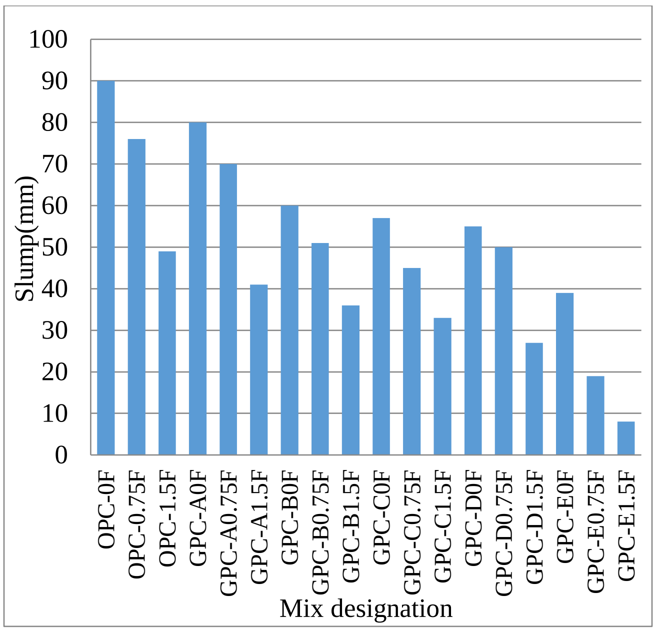


Figure 2: The result of slump test of the mixes

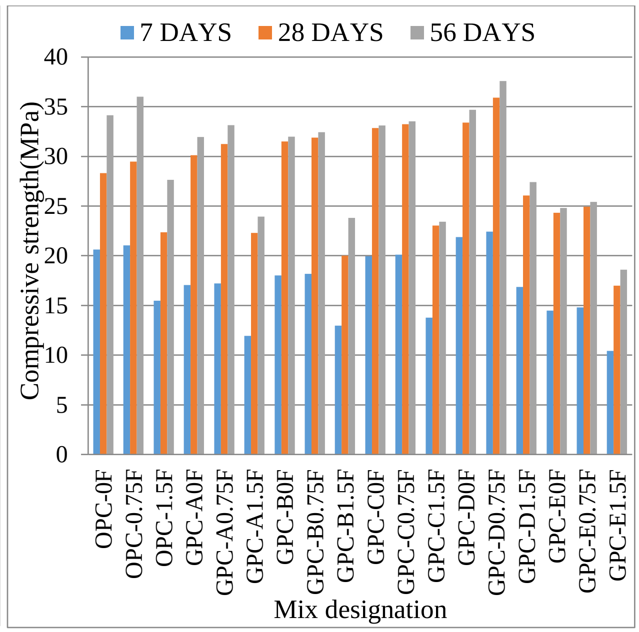


Figure 3: The result of compressive tests of the mixes

3.3 Splitting tensile strength

It can be observed from Figure 4 that splitting tensile strength of GPC mixes improved with the increase of QRD content up to 15% and SF up to 0.75%. After a further increase of QRD and SF resulted in a decreased strength of GPC mixes, due to a considerably low workable mix and a heterogeneous blend with improper distribution of SF in the mix, which ultimately reduced the splitting tensile strength. The maximum strength observed from the results is by GPC-D0.75F which has 9% more strength than its corresponding OPC concrete control mix. The splitting tensile strength of different mixes can be observed from Figure 4.

3.4 Flexural strength

It is an important property which affects the bending characteristics and brittleness ratio of concrete in structural concrete design. Figure 5 depicts the influence of QRD content and SF on flexural strength of GPC mixes. The flexural strength of the GPC mixes follows the similar trends as was observed for the compressive and splitting tensile strengths. The maximum strength was obtained by GPC-D0.75F with 15% QRD and 0.75% SF. The flexural strength of this GPC mix is 13% higher than its corresponding OPC control specimen due to better compactness and ductile nature.

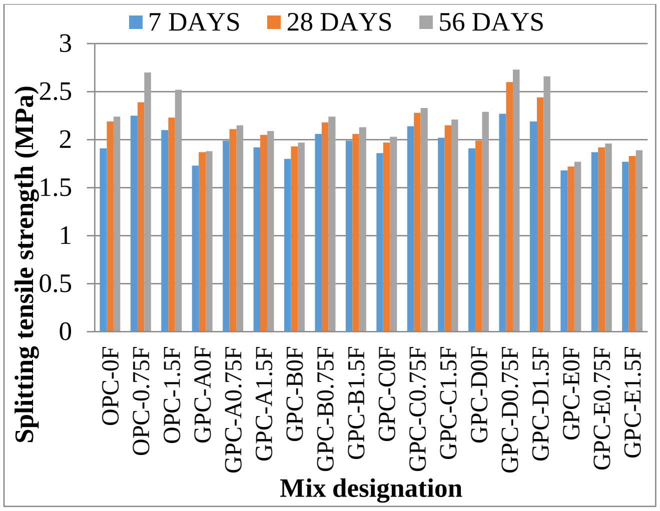


Figure 4: The result of tensile tests of the mixes

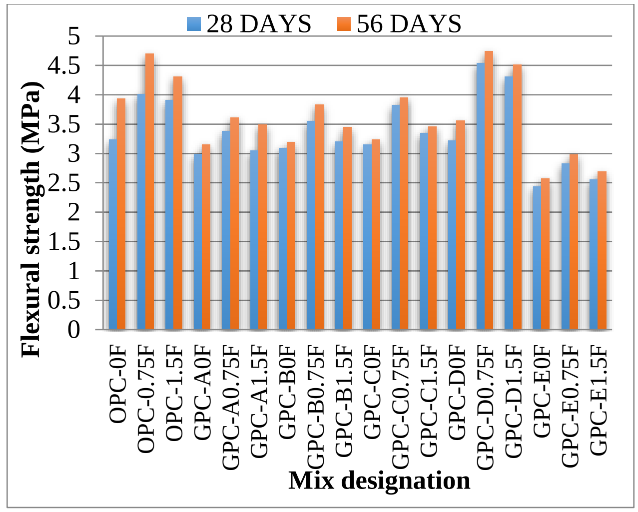


Figure 5: The results of flexural tests of the mixes

4 PRACTICAL APPLICATION

Generally GPC has limited field application due to its limitation pertaining to heat curing for achieving a better strength. Due to this reason, the precast units of GPC has been manufactured and used in the field. The incorporation of calcium rich binder like SG and QRD makes possible the production of GPC at ambient temperature curing with good strength properties; hence, expanding its application to the areas beyond precast members. This also reduces the energy and cost associated with the heat curing.

5 CONCLUSIONS

Following conclusions can be drawn from this study:

1. The workability of GPC mixes deteriorates as QRD and SF incorporation increases.
2. Maximum compressive, splitting tensile and flexural strengths at ambient temperature curing was obtained by GPC-D0.75F which has 15% QRD of total binder and 0.75% SF by volume.
3. A substantial reduction was observed in the mechanical properties of GPC mixes when QRD was increased from 15% to 20% and steel fiber fraction from 0.75% to 1.5%. Hence, the optimum quantity to be used for achieving a superior GPC mix (than the OPC concrete) with an acceptable workability is with 15% QRD replacement with SG and 0.75% SF for a low calcium FA-SG based GPC mix.

REFERENCES

[1] M. Sumesh, U. J. Alengaram, M. Z. Jumaat, K. H. Mo, and M. F. Alnahhal, "Incorporation of nano-materials in cement composite and geopolymer based paste and mortar – A review," *Construction and Building Materials*. 2017.

[2] A. Sharmin, U. J. Alengaram, M. Z. Jumaat, M. O. Yusuf, S. M. A. Kabir, and I. I. Bashar, "Influence of source materials and the role of oxide composition on the performance of ternary blended sustainable geopolymer mortar," *Constr. Build. Mater.*, 2017.

[3] M. F. Alnahhal, U. J. Alengaram, M. Z. Jumaat, M. A. Alqedra, K. H. Mo, and M. Sumesh, "Evaluation of industrial by-products as sustainable pozzolanic materials in recycled aggregate concrete," *Sustain.*, 2017.

[4] M. T. Junaid, A. Khennane, O. Kayali, A. Sadaoui, D. Picard, and M. Fafard, "Aspects of the deformational behaviour of alkali activated fly ash concrete at elevated temperatures," *Cem. Concr. Res.*, vol. 60, pp. 24–29, 2014.

[5] Parveen, D. Singhal, M. T. Junaid, B. B. Jindal, and A. Mehta, "Mechanical and microstructural properties of fly ash based geopolymer concrete incorporating alccofine at ambient curing," *Constr. Build. Mater.*, vol. 180, pp. 298–307, 2018.

[6] P. Nath and P. K. Sarker, "Effect of GGBFS on setting, workability and early strength properties of fly ash geopolymer concrete cured in ambient condition," in *Construction and Building Materials*, vol. 66, pp. 163–171,

2014.
[7] M. G. and J. G. Sanjayan, "Behavior of combined fly ash/slag-based geopolymers when exposed to high temperatures," *Fire Mater.*, vol. 34, pp. 163–175, 2010.
[8] I. Ismail, S. A. Bernal, J. L. Provis, S. Hamdan, and J. S. J. Van Deventer, "Microstructural changes in alkali activated fly ash/slag geopolymers with sulfate exposure," *Mater. Struct. Constr.*, vol. 46, pp. 361–373, 2013.
[9] M. Chi and R. Huang, "Binding mechanism and properties of alkali-activated fly ash/slag mortars," *Constr. Build. Mater.*, vol. 40, pp. 291–298, 2013.
[10] J. Temuujin, A. van Riessen, and R. Williams, "Influence of calcium compounds on the mechanical properties of fly ash geopolymer pastes," *J. Hazard. Mater.*, vol. 167, pp. 82–88, 2009.
[11] D. Dutta and S. Ghosh, "Effect of lime stone dust on geopolymerisation and geopolymeric structure," 2012.
[12] A. Islam, U. J. Alengaram, M. Z. Jumaat, N. B. Ghazali, S. Yusoff, and I. I. Bashar, "Influence of steel fibers on the mechanical properties and impact resistance of lightweight geopolymer concrete," *Constr. Build. Mater.*, vol. 152, pp. 964–977, 2017.
[13] T. Venu Madhav, I. V. Ramana Reddy, V. G. Ghorpade, and S. Jyothirmai, "Compressivestrength study of geopolymer mortar using quarry rock dust," *Mater. Lett.*, vol. 231, pp. 105–108, 2018.
[14] B. K. Meisuh, C. K. Kankam, and T. K. Buabin, "Effect of quarry rock dust on the flexural strength of concrete," *Case Stud. Constr. Mater.*, vol. 8, pp. 16–22, 2018.
[15] K. S. Prakash and C. Hanumantha Rao, "Strength Characteristics of Quarry Dust in Replacement of Sand," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 225, p. 012074, 2017.
[16] ASTM C150-07, "Standard Specification for Portland Cement," *ASTM Int.*, 2007.
[17] J. S. J. van Deventer, J. L. Provis, P. Duxson, and G. C. Lukey, "Reaction mechanisms in the geopolymeric conversion of inorganic waste to useful products," *J. Hazard. Mater.*, vol. 139, pp. 506–513, 2007.
[18] ASTM C136-06, "Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates," *ASTM Int.*, 2006.
[19] ASTM C128-15, "Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate," *ASTM Int.*, 2015.
[20] ASTM C127-07, "Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate," *ASTM Int.*, 2007.
[21] ASTM A820-11, "Standard Specification for Steel Fibers for Fiber-Reinforced Concrete," *ASTM Int.*, 2011.
[22] ASTM C494-15, "Standard Specification for Chemical Admixtures for Concrete," 2015.
[23] ASTM C143/C143M-15, "Standard Test Method for Slump of Hydraulic-Cement Concrete," *ASTM Int.*, 2015
[24] ASTM C39-08, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens ," *ASTM Int.*, 2008.
[25] ASTM C496-11, "Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens," *ASTM Int,*. 2011.
[26] ASTM C1609/C 1609M-05, " Standard Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam With Third-Point Loading) ," *ASTM Int.*, 2005.
[27] N. Venkata Sairam Kumar and K. S. Sai Ram, "Experimental study on properties of concrete containing crushed rock dust as a partial replacement of cement," *Mater. Today Proc.*, vol. 5, pp. 7240–7246, 2018.
[28] A. S. Sayyad and S. V. Patankar, "Effect of Steel Fibres and Low Calcium Fly Ash on Mechanical and Elastic Properties of Geopolymer Concrete Composites," *Indian J. Mater. Sci.*, vol. 2013, pp. 1–8, 2013.
[29] P. S. Deb, P. Nath, and P. K. Sarker, "The effects of ground granulated blast-furnace slag blending with fly ash and activator content on the workability and strength properties of geopolymer concrete cured at ambient temperature," *Mater. Des.*, vol. 62, pp. 32–39, 2014.

2[nd] Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

CHARACTERIZATION OF BRICK MASONRY OF OLD AND NEW BUILDING BLOCKS AT GCT RASUL

[a] Engr. Asif Nazir
a: Department of Technology (Civil Division, Civil Engineering Technology),
The University of Lahore, Lahore, Punjab, Pakistan.
Email: Asifnazir835@gmail.com

Abstract- In historical buildings the clay brick masonry was used in too much quantity. In order to characterization of brick masonry of old and new building block at GCT Rasul, for this purpose 12 samples of clay brick specimen, cement and lime mortar were collected from main (old) building block and B-Tech new building block. All the collected samples were characterized and evaluated physically, chemically and mechanically. After study and evaluation, the large variation in the properties was found. Furthermore, the sample of lime mortar which was used for the construction of main building block and the sample of cement mortar which was used for the construction of new B-Tech building block were also analyzed. The result of main (old) building and new B-Tech building were compared. And a significant difference was found in chemical properties, mechanical properties, water absorption, porosity, of old bricks was high which was constructed by using lime mortar and the water absorption and porosity of new building bricks was low which was constructed by using cement mortar. The main building block and new B-Tech building block were constructed 1912-16 and 1980-86 respectively.

Keywords- Clay Bricks, XRD Of Brick, Physical And Mechanical Test Of Brick, Chemical Composition Of Mortar

1 INTRODUCTION

The Government College of Technology Rasul is housed in a spacious, well maintained two hundred- and fifteen-acres area. It is located about 40 km away from G.T road approachable from Kharian and Sara-e-Alamgir whereas 14 km from District Headquarter Mandi Bahauddin through road.

1.1 Material and Method

The brick, cement mortar and lime mortar used in this work was raw material collected from two different sources namely Main building block and B-Tech building block situated in GCT Rasul. The lime mortar is to be used for the construction of Main building block and cement mortar is to be used for construction of B-Tech building block. Brick sample were collected namely MB1, MB2, MB3, MB4, MB5 and MB6 from Main Building block and BT1, BT2, BT3, BT4, BT5, and BT6 from B-Tech building block respectively.

Ingredients of good brick earth

Silica	50-60%
Alumina	20-30%
Lime	10%
Magnesia	< 1%
Ferric oxide	< 7 %
Alkalis	< 10%
Carbon dioxide	Very small %
Sulphur trioxide	Very small %
Waters	Very small %

Figure 25:Ingredients of good brick earth

In this study an effort will be made to find the better combination, when damaged historical masonry needs to be restored with substitution bricks, a good characterization of both new and old material lets us forecast the chemical behaviour of the system.

2 RESULTS AND DISCUSSION

2.1 *Chemical Composition of Cement and Lime Mortar*

Chemical compositions of cement and lime mortar samples are presented in Table 1.1. It was observed that the silica content approximately 12.7 % higher in cement mortar and a miner difference of Calcium Oxide (CaO) in between cement and lime mortar.

Table 1: Chemical composition of cement and lime mortar

S/No	Element	% Cement mortar used in B-Tech Department Block	% Lime mortar used in Main Building Block
1	Calcium Oxide (CaO)	11.76 %	10.36 %
2	Silica (SiO2)	73.20 %	60.50 %
3	Magnesium Oxide (MgO)	01.60 %	02.40 %
4	Alumina (Al2O3)	03.10 %	06.20 %
5	Iron Oxide (Fe2O3)	01.10 %	02.41 %
6	Losses on Ignition (L.O.I)	07.60 %	09.90 %
7	Sulfur Trioxide (SO3)	01.72 %	02.65 %
8	Ratio	Cement: Sand; 1: 4.17	Lime: Sand 1: 4.87

2.2 *X-Ray Diffraction (Xrd) Analysis of Bricks*

X-ray diffraction XRD was performed on all 12 brick samples (6 collect from Main (old) Building block & 6 from B-Tech (new) building block) throughout this thesis. The most prevalent mineral found throughout the study was quartz. This was seen not only in the brick samples. From the compositional consistencies seen throughout the 12 brick samples, it was ascertained that the bricks from Old & New building block were all locally manufactured. Bricks were observed to be compositionally similar. Though different in intensities, the presence of quartz was consistent in both samples. Typically, it was observed that the darker bricks contained hematite, which has been seen experimentally in bricks that are fired at hotter temperatures, usually above 900^o C.
X-ray diffraction pattern of Main building block (100 years old) brick and B-Tech building block brick are presented in Fig 2. Peak 2θ degree positions for the main building block brick sample [Fig 1] at 26.82, 36.88, 50.22, 60.44 and 68.30 with the maximum relative intensity and those for B-Tech building block brick sample [Fig 1.2] at 20.76, 26.66, 34.60, 50.06 and 68.16, with the maximum relative intensity; clearly show the presence of quartz in the samples. Quartz (SiO_2) is a common constituent of granite, sandstone and limestone. Sharpness of peaks in the XRD spectra also indicates that SiO_2 could be in the crystalline form. XRD- spectrum of sample indicated that the main composition of sample was a-quartz.

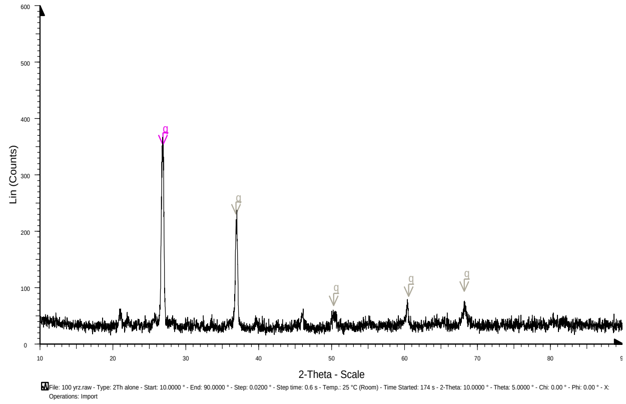


Figure 2: XRD Pattern for 100-year-old brick of Main building block

3 DESCRIPTION OF THE ORIGIN AND MEASUREMENT THE SIZES OF BRICKS

ASTM C-67-03a is used to determine the sizes of bricks samples collected from the main and B-Tech building block. The measurement sizes test results are summarized in table 1.2. It is noticeable that the length and width of 100 years old bricks collected from Main building block is 18 % and 12 % greater as compared to the B-tech building block brick respectively. The thickness of bricks used in these building blocks is almost same.

Table 2: Comparison of sizes of Main and B-Tech building blocks

Monument	Construction period	Location	Dimension (mm)	Specimen Name
GCT Rasul	1912-16	Main Building Block	260x128x70	MB1
			260x126x70	MB2
			246x120x70	MB3
			260x128x70	MB4
			259x127x69	MB5
			246x121x70	MB6
	1980-85	B-Tech Building Block	220x115x70	BT1
			221x115x69	BT2
			220x114x70	BT3

3.1 Compressive Strength and Bulk Mass of Brick Specimens

ASTM C-67-03a is used to determine the compressive strength and bulk mass of brick samples, collected from main and B-tech building block at GCT Rasul. The Table 1.4 and Fig 1.3 shows the compressive strength (fc') and bulk mass result of 100 years old (Main building block) and new building block (B-Tech building) brick samples.

Generally, a large variability on the compressive strength was obtained on B-Tech building block brick samples with highest 20.399 MPa on BT2 sample brick and lowest value 13.640 MPa on sample BT6 brick sample. Similarly, a small variability on the compressive strength as well as bulk mass were obtained on 100 years old brick samples (Main building block) with a highest value 23.712 MPa on sample No MB3 brick and lowest value 19.399 MPa on sample No MB5 brick.

Table 4 and Figure 3 clearly shows that the compressive strength of Old building block (Main building block) brick samples is 39 % greater to the new building block (B-Tech building block) brick samples.

S/No	Area	Load	Compressive strength fc'	Bulk mass
	mm2	N	(MPa)	Kg/m3
MAIN BUILDING BLOCK				
MB1	33280	648065	19.473	1707.589
MB2	32760	707886	21.608	1687.162
MB3	29520	700000	23.712	1761.033
MB4	33280	658035	19.772	1707.160
MB5	32893	638095	19.399	1718.351
MB6	29766	687946	23.111	1751.758
Average			**21.180**	**1722.175**
B. TECH BUILDING BLOCK				
BT1	25300	368898	14.580	1405.985
BT2	25415	518452	20.399	1417.056
BT3	25080	348958	13.913	1434.267
BT4	25300	358928	14.186	1402.597
BT5	25530	378868	14.840	1407.835
BT6	24852	338988	13.640	1419.833
Average			**15.260**	**1414.595**

4 CONCLUSIONS

Based on the experimental study on the brick's samples, cement and lime mortar following conclusions can be drawn

- The XRD study conclusively establishes the presence of quartz in the brick samples.
- The sizes of bricks especially length and width used for the construction of Main building block are greater than bricks used in B-tech building block approximately 40 mm and 14 mm respectively. Therefore, new bricks could not be used for replacement of old bricks in the damaged portion of 100 years old Main building block masonry.
- The lime mortar with ratio (1:4.87) and cement mortar with ratio (1:4.17) are to be used for the construction of Main and B-tech building block masonry respectively.
- The compressive strength and bulk mass of brick used for the construction of Main building block is approximately 39 % and 22 % respectively greater than brick used for the construction of B-Tech building block. Therefore, old brick is most durable as compare to new building block brick.

So, it is concluded for characterization of brick masonry of old and new building blocks at GCT Rasul, that the width of wall is so greater because the length of old brick is greater therefore, at this stage masonry of old building block is durable and well condition.

Figure 3: a) Photo of Main building block (Old block); b) Photo of B-Tech building block (New block)

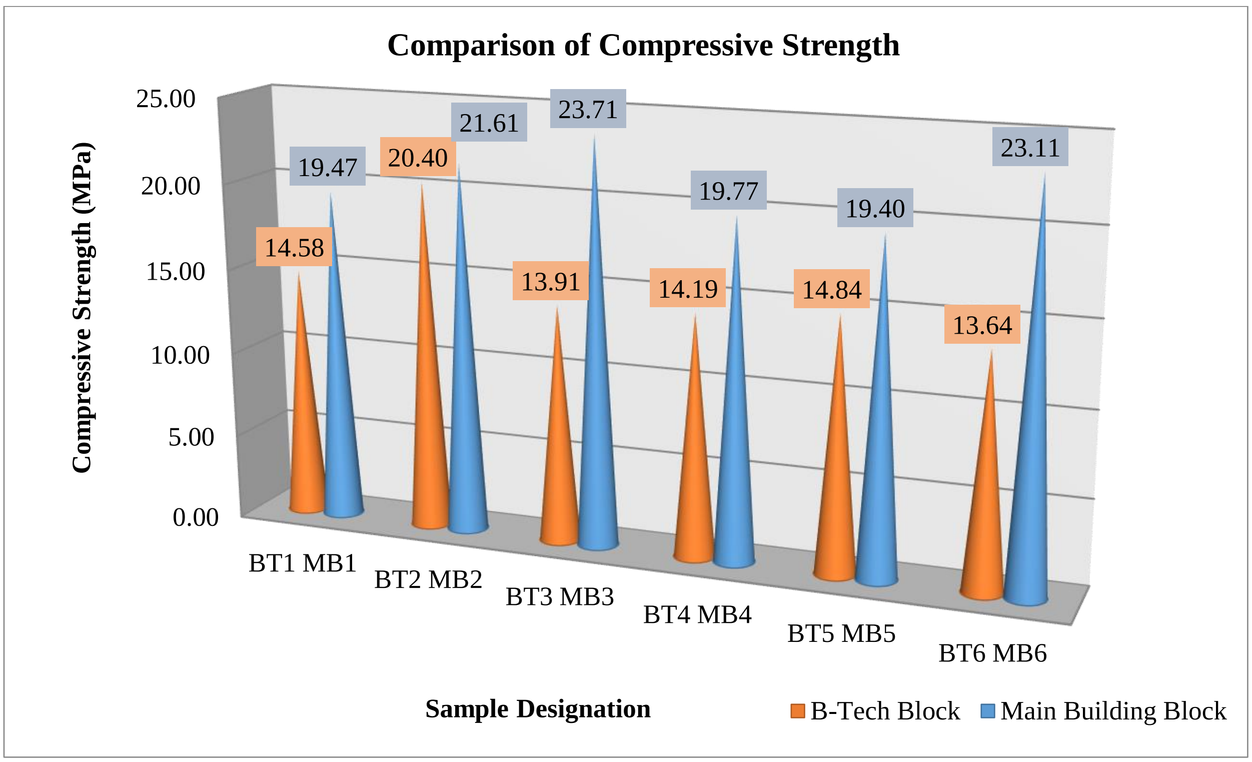


Figure 4: Graph showing the Compressive Strength of Brick

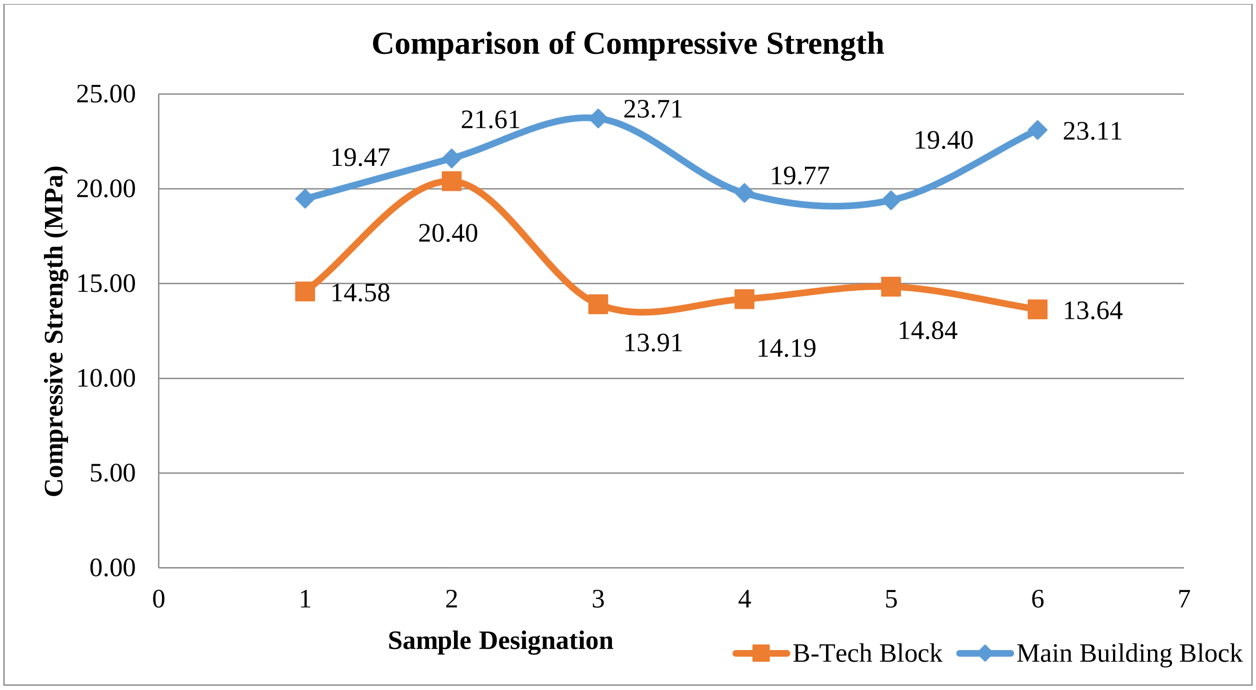


Figure 5: Graph showing the Compressive Strength of Brick

REFERENCES

1. Kerstin Elert, Giuseppe Cultrone, carlos Rodriguez Navarro, from Durability of bricks used in the conservation of historic buildings" Journal of Cultural Heritage 4 (2003) 91-99 accepted10 Feb, 2003.
2. Paula Lopez-Arce studied on "Bricks in historical building of Toledo city" Materials Characterization 50 (2003) 59-68 accepted 2 June, 2003.
3. Paulo B. Lourenço ISISE, Department of Civil Engineering University of Minho, Azurém, P 4800-058 Guimarães, Portugal have done research on "Characterization and damage of brick masonry"
4. Richards RW, Brick manufacturing from past to present, Ceram Bull 1990;69(5):807-13
5. Moropoulou A, Bakolas A, Bisbikou K. Thermal analysis as a method of characterizing ancient technologies. Thermochim Acta 1995;269:743-53
6. Md Raheijuddin Sheikh "X-ray diffraction and Fourier transform infrared spectra of the bricks of the Kamakhya temple Indian Journal Vol. 51, November 2013, pp. 745-748.
7. Paola Cardiano "Study and characterization of the ancient bricks of monastery of San Filippo di Fragala in Frazzano (Sicily) Analytica Chimica Acta 519 (2004) 103-111
8. C. Filangeri, Monasteri Basiliani di Sicilia, Messina, 1979
9. G. Cultrone "Mineralogical and physical behavior of solid bricks with additives" show that the presence of additives" construction and building materials 19 (2005) 39-48
10. Warren J. Conservation of bricks. Oxford: Butterworth Heinemann; 1999. p, 1-294

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

SUSTAINABLE BUILDINGS AND INFRASTRUCTURES DEVELOPMENT USING INNOVATIVE MATERIAL AND ADVANCE TECHNOLOGIES-A REVIEW

[a] Hammad Bashir, [b] Hassan Akhtar, [c] Adnan khan
a: Assistant Resident Engineer, Engineering Services Consultant, hammad.bashir@gmail.com
b: Civil engineering Department, Lahore Leads University, Engr.Hassanakhtar@gmail.com
c: Civil Engineering Department, Preston University Lahore, adnankhanchandia@gmail.com

Abstract- For a meaningful growth about global sustainable development, sustainability attainment in affordable housing and infrastructure development is fundamental. With the unsustainable use of energy and growing ecological issues of the industries, there is attention in our globe. The general objective of this research paper is to review the research's regarding sustainability. The specific goal is to focus on buildings and infrastructure sustainability. In methodology, Green building and infrastructure development researches are reviewed, sustainable house construction using recycle material prepared for interlocking blocks are considered, building information modeling (BIM) role adapted to improve efficiency. The output of these methodologies based on the best solutions for sustainable life are reported. This paper will help in providing the practical approach and valuable effect of sustainability on the environment.

Keywords- Sustainability, Green Buildings, Interlocking Blocks, Ecological Issues, Building Information Modelling.

1 INTRODUCTION

Over the last decade, much effort has been spent trying to deeply understand sustainable development, both as a concept and, no less important, in a practical sense. The sustainability output of a single construction project over its life cycle is an Influential factor in achieving the goal of development. Reports by the World Commission on Environment [1] defined Sustainable development as an accumulation of public basic demand and fulfillment of their hopes for a better life without sacrificing future generation abilities. This concept puts an emphasis on a balance between social growth, economic development and environmental sustainability. This concept emphasizes a balance between social growth, economic development, and environmental sustainability. By accepting this idea, the influence on sustainable development of construction activities can be deemed in three main areas: social, economic and environmental. Building blocks account for 40 percent of total emissions, as per the Globe Business Council for Sustainability [2]. The concept of sustainability [3] Being used in the multinational society, evolving the concept of the triple bottom line. The triple bottom statement relates to the three pins of political, ecological and economic results that are directly related to the sustainable development principle and goal.

The construction industry has a profound effect on ecological, social and economic society. It is noting that green building was used as a synonymous concept for feasible construction and strong-performance construction. Robichaud and Anantatmula [4] noted, that four foundations of green buildings exist, that is to say, minimizing environmental consequences and improving Occupancy fitness, come back to equity to entrepreneurs and the local community and consideration of the life-cycle of strategic planning. A green building [5] simple definitions (e.g. strictly environmental sustainability) or specific definitions (e.g. implementation a triple bottom line approach) [6]. Moreover, the importance of the social, economic and cultural elements of sustainable green building growth is rarely mentioned [7]. Such a literature review plays an important role not only in identifying common research streams but also in addressing economic trends in studies. The Construction sector implementation [8] Goals in a comprehensive way of restoring and preserving cohesion between the natural and the built world, in a way that establishes settlements that uphold fundamental human rights and foster economic equality. Infrastructure provides for and supports vital human capabilities [9]. Infrastructure Structures do not only have advantageous effects. The environmental and social effects of facilities could be incredibly damaging, all specifically during development and in more pervasive ways, within beyond the working life of raw materials. On the other side, infrastructure is important for reducing human effects on the environment, allowing humans to stay in cities, including the treatment of wastewater and the collection of garbage, recovery and recycling technologies. There is growing interest in the prospect of replacing 'grey infrastructure' with 'green infrastructure'[10]. For illustration, using lagoons and foreshores for the treatment of sewage [11]. Wetlands help that recover freshwater aquifers and afforestation to replace for flood control.

Sustainability in Building construction can be achieved by interlocking blocks. Interlocking blocks are distinguished from commonly used bricks because they do not allow mortar to be put during the bricklaying process [12]. When using these powerful alternative approaches, the repetitive and time-consuming conventional brick-laying activities are greatly simplified [13]. Building Information Modeling (BIM) is described in a number of ways, including BIM as a service, process or mechanism/applications. As its BIM is not confined to technology, it is known that BIM uses a collective visual image of the constructed object to encourage planning, building and service processes and provide a transparent framework for policymaking [14]. A need to recognize viable administration and strategy systems utilizing advanced feasible methods are essential for sustainable construction. The study suggested that the importance of good engineering evaluations in the design based on sustainability, which cannot just be done considering standard methods. It requires a point by point assessment of local and global behavior of the building.

2 NEED OF SUSTAINABILITY IN CONSTRUCTION

Along with Energy generation and automotive use, the construction sector is one of the three biggest contributors to greenhouse gases which threaten the Earth's climate [15]. The construction industry has important social and environmental effects on society. Buildings are one of the main outputs of the construction sector and infrastructures such impacts are largely expressed throughout its life cycle. The detrimental effects of construction tasks include the provision of buildings and services to meet the needs of people, and job opportunities direct or indirect (by other construction-related industries) and leading upwards to the national economy.

Table 1- Concepts of sustainability

Sr.	Concept	Construction Sustainability	Authors
1	Sustainable development	Sustainable construction involves not only new, environmentally friendly construction designs, and also have new, eco-friendly operations and maintenance processes.	Reffat, 2004
2	Sustainability performance	Sustainability of building efficiency is essential to the achievement of sustainable growth. Previously, different strategies and management skills have been built to further enhance the sustainable performance of construction projects.	Shen et al. 2007
3	Sustainable construction	Sustainable Construction in Developing Countries has recommended a plan to tackle many of these challenges are generated by setting up a research and development strategy focused on an immediate, shorter and longer-term continuum of technological, structural and cost-added enablers.	Plessis 2007
4	Sustainable material	Sustainable construction can be achieved through using sustainable construction material made interlocking blocks.	Nasly, M., 2009
5	Green Building Sustainability	Green building is one of the steps introduced to minimize the major environmental, social and economic impacts of the building stock.	Zuo, Z.and Zhao 2014
6	Lean Sustainability	The Lean-Sustainability Framework for the delivery of infrastructure illustrates features such as tools, drivers, obstacles, events, outputs, outcomes and the ultimate impact. The findings provide insight into the different elements of the design.	Isa et al. 2018

7	Infrastructure sustainability	Sustainable development for Infrastructures	Thacker et al. 2019

The detrimental effects of buildings and development tasks are also well identified. Those include pollution, noise, traffic jams, water contamination and disposal of waste throughout the construction phase. A huge volume of material and human energy has been used. Once completed, buildings will continue to have environmental impacts. The natural resources are small and have some technical innovations, human needs are constantly rising. Deforestation is affecting environmental protection on a global scale, with further negative effects on developing countries. The deforestation results include global warming, drought, environmental degradation, water and air pollution. Sustainability is important to control all these issues.

3 Sustainable Development Towards Infrastructure And Buildings System

The huge investments now being made in infrastructure and building systems are influenced by the rapid urbanization towards cities, population growth towards all over the world and industrialization of developing states. Huge stock of declining infrastructure assets exists in most high-income countries that need replacement, reconstruction or elimination, which means that significant improvements are required Also in countries where the network is fairly well defined and established systems. These investments are in many situations not primarily motivated by sustainability investments in infrastructure also undertake generations to come to running and maintaining expenses, which can occupy large quantities of the state finances confined. Wasteful investment on patronage schemes is weakening public interest and revenue commitment.

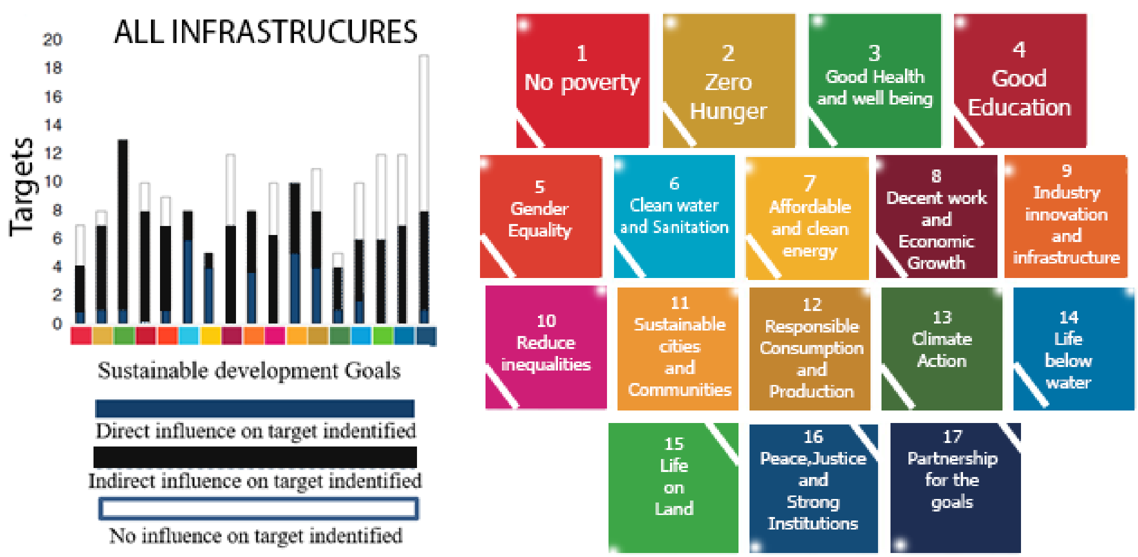


Figure 1: Goals are partitioned by the number of targets to recognize direct or indirect impacts

Each goal is partitioned by the number of objectives and an evaluation of each outcome to recognize direct or indirect impacts from the development of the five infrastructure types. Figure (2) represents that all infrastructure demonstrates the collective impact of the five infrastructure sectors on sustainable development goals. This includes a target whether it can be affected by one or more of the five infrastructure areas. Where a target is directly and indirectly affected by various infrastructure schemes, the target is labeled as direct.

Infrastructure is part of sustainable development goals. But it is identified that there are far wider benefits to sustainable development [16]. The figure presents the results of an analysis. To what extent infrastructure structures impact sustainable development outcomes, as described by SDG (Sustainable development goal) goals estimated. If we agree to affordable development for the poorest, the social facilities and human dignity sought by the SDGs would be denied to millions of people. By concentrating on infrastructure resilience, therefore, the potential to gain effect through the SDGs on a scale that would otherwise be difficult. The political commitment that the SDGs help generate should be backed up by databases, resources and methodologies to direct investment decisions towards sustainability.

4 SUSTAINABILITY ACHIEVEMENT THROUGH DIFFERENT METHODS

4.1 Sustainability through Green Buildings

Green Building is one of the initiatives proposed to reduce the environmental, social and economic influences of the building inventory. It is important to note that green construction was modified as a concept synonymous with strong-performance building sustainable construction. Robichaud and Anantatmula figured out that some green buildings have four key components, i.e. environment influences mitigation, improving the health conditions of the residents, the profit margin to innovators and indigenous communities, And recognition of the life-cycle during planning and growth process [17]. Green building surveys concentrate on sustainability, environmental aspects such as water efficiency, energy consumption and greenhouse gas emissions alongside scientific alternatives. The social and economic parts are relatively lean, although many literatures emphasize the significance. The social output, for illustration, regarding green building justifies internal review. The evaluation strategy of life cycle, that has been extensively applied on the ecological and technological aspects of green buildings.

Figure 2: Sustainability of Green Buildings

4.2 Sustainable Housing Using an Innovative Material interlocking blocks

Nominal brick is the main building material for the structure's construction due to significant development and growth in the construction field. Engineers are in the chase for advanced building material based on durability, economy and efficiency. With the increase in the cost of materials in the construction sector, more price-saving solutions need to be found to sustain the cost of building houses at rates that are efficient to the customers. Sustainability could be accomplished by the use of rice husk ash (RHA) as a cement substitute through the use of Palm Oil Fly Ash (POFA) as an aggregate of recycled concrete and related building wastes [12]. Materials need for block development and construction are generally available locally in many other areas; Thus, construction using interlocking blocks has environmental advantages in areas where wood is expensive. (No habitat loss, low energy demands criteria for block manufacturing and transportation). At the building site (for self-sustained construction), or on a large scale in integrated production models, these blocks may be made on a small scale. Masonry does not need a sophisticated machine or machinery; it can be made with local materials with optimum moisture and stabilizers on hand. However, there is considerable variance in the strength of the block and the quality of the masonry as the aspect ratio of the masonry and the interlocking makes a significant difference in all structural dimensions of the masonry.

Figure 3: a. Innovation material interlocking blocks b. House construction using innovative material c. Sustainable house.

4.3 Building Information Modelling (BIM) Advance technology for Sustainable Projects

Nominal brick is the main building material for the structure's construction the survivability BIM has with sustainability in the Architecture, Engineering and Construction (AEC) sectors are of great importance [18]. Using Building Information Modelling (BIM) data gathered during design and construction over the entire lifespan of the project allows for faster, better, less wasteful production and more price-effective, sustainable operation, repairs and eventual reprocessing. The BIM contribution provided by all project partners contributes to sustainability in several ways: The reallocation of technical, operational, construction and manufacturing understanding allows the design to be value-engineered and optimized for every level of service and operation.

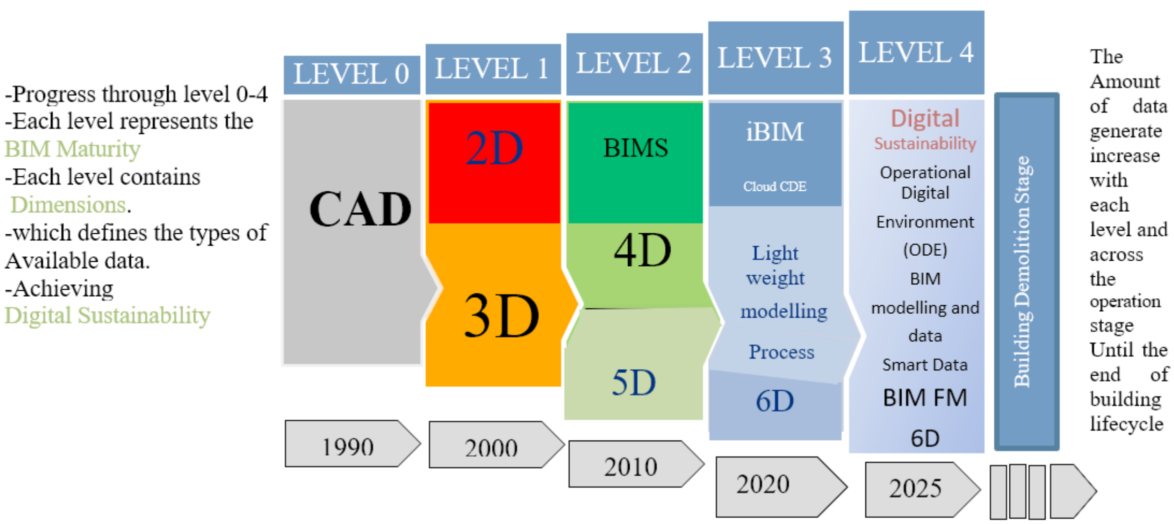


Figure 4: Building information modelling maturity level

The nature of the shared knowledge is based on the BIM dimensions. Every dimension develops upon the preceding one to provide extra project details. Figure 5 shows that 2D represents two-dimensional construction drawings with an x and y axis. 3D represents three-dimensional drawings with an accumulating z-axis.4D represents three-dimensional elaborate with the added element of scheduling.5D shows three-dimensional drawings with scheduling and budget information.6D shows three-dimensional drawings with information on scheduling, budget, maintenance and sustainability.BIM is being used to digitally design and develop a building. Previously, National technology of. Each occurrence of the construction phase can be digitally plotted, from the design, planning and eventual start of construction. In construction industry many buildings are developed using sustainable new technologies and advance materials. National Science and Technology park are one the example in National University Pakistan that was adopted sustainable development and work for multi-disciplinary functions.

5 CONCLUSION

The results of this comprehensive study of the collective design method show that there are contradictions of sustainable development systems that can be addressed through the employment of different methods. Either choosing sustainable material or considering the sustainability sphere of social, environmental and economic aspects. This promotes both research and practice to develop and adapt innovative approaches to tackle problems relevant to practical, economic, technological and operational concerns for future generations. A need to identify effective management and policy strategies using digital sustainable tools are required.

RECOMMENDATIONS

It is essential to implement the use of existing and new knowledge for digital innovations. For sustainable development, an indispensable application of collecting data would be best to resolve the issues. There is need to incorporate the dynamic performance of sustainable environment using the digital era in sustainable construction that will bring opportunities to improve the coherence achievement of sustainable development goals for new generations.

REFERENCES

[1] S. Imperatives, "Report of the World Commission on Environment and Development," 1987.
[2] A. B. Council, "Building Energy Efficiency : Why Green Buildings are Key to Asia ' s Future Building Energy Efficiency : Why Green Buildings Are Key to Asia ' s Future," *October*, no. October, 2008.
[3] R. M. Reffat, "Sustainable construction in developing countries," *Proc. First Archit. Int. Conf. Cairo Univ. Egypt*, pp. 1–8, 2004.
[4] L. B. Robichaud and V. S. Anantatmula, "Greening project management practices for sustainable construction," *J. Manag. Eng.*, vol. 27, no. 1, 2011.
[5] H. ALwaer and D. J. Clements-Croome, "Key performance indicators (KPIs) and priority setting in using the multi-attribute approach for assessing sustainable intelligent buildings," *Build. Environ.*, vol. 45, no. 4, 2010.
[6] Q. Shi, J. Zuo, R. Huang, J. Huang, and S. Pullen, "Identifying the critical factors for green construction - An empirical study in China," *Habitat Int.*, vol. 40, pp. 1–8, Oct. 2013.
[7] R. Mateus and L. Bragança, "Sustainability assessment and rating of buildings: Developing the methodology SBToolPT-H," *Build. Environ.*, vol. 46, no. 10, pp. 1962–1971, Oct. 2011.
[8] C. Du Plessis, "Agenda 21 for sustainable construction in developing countries," *CSIR Rep. BOU E*, no. 2, pp. 2–5, 2002.
[9] S. S. Clark, T. P. Seager, and M. V. Chester, "A capabilities approach to the prioritization of critical infrastructure," *Environ. Syst. Decis.*, vol. 38, no. 3, pp. 339–352, Sep. 2018.
[10] W. Sohn, H. W. Kim, J. H. Kim, and M. H. Li, "The capitalized amenity of green infrastructure in single-family housing values: An application of the spatial hedonic pricing method," *Urban For. Urban Green.*, vol. 49, p. 126643, Mar. 2020.
[11] J. Vymazal and T. Březinová, "The use of constructed wetlands for removal of pesticides from agricultural runoff and drainage: A review," *Environment International*, vol. 75. Elsevier Ltd, pp. 11–20, 01-Feb-2015.
[12] M. A. Nasly and A. A. M. Yassin, "Sustainable Housing Using an Innovative Interlocking Block Building System," *Int. J. Civ. Eng. Geo-Environmental*, vol. 1, no. 1, pp. 1–9, 2010.
[13] W. A. Thanoon, M. S. Jaafar, M. R. Abdul Kadir, A. A. Abang Ali, D. N. Trikha, and A. M. S. Najm, "Development of an innovative interlocking load bearing hollow block system in Malaysia," *Constr. Build. Mater.*, vol. 18, no. 6, pp. 445–454, Jul. 2004.
[14] C. Panteli *et al.*, "Overview of BIM integration into the Construction Sector in European Member States and European Union Acquis," in *IOP Conference Series: Earth and Environmental Science*, vol. 410, no. 1, 2020.
[15] K. A. Mir, C. Park, P. Purohit, and S. Kim, "Comparative analysis of greenhouse gas emission inventory for Pakistan: Part I energy and industrial processes and product use," *Adv. Clim. Chang. Res.*, May 2020.
[16] A. Karmi, "How Smarter Technology Will Feed the Planet," *Scientific American*, 2019.
[17] Y. Geng, W. Ji, Z. Wang, B. Lin, and Y. Zhu, "A review of operating performance in green buildings: Energy use, indoor environmental quality and occupant satisfaction," *Energy and Buildings*, vol. 183. Elsevier Ltd, pp. 500–514, 15-Jan-2019.
[18] S. Alizadehsalehi, A. Hadavi, and J. C. Huang, "From BIM to extended reality in AEC industry," *Autom. Constr.*, vol. 116, p. 103254, Aug. 2020.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

CRITICAL SUCCESS FACTORS FOR SUSTAINABLE BUILDING CONSTRUCTIONS-A REVIEW

[a] Ali Rehman, [b] M Abbas Arshad, [c] Aziz un Nabi
a: Lecturer, Department of Civil Engineering, Comsats University Islamabad, Abbottabad Campus, alirehman@cuiatd.edu.pk.
b: Planning Engineer, Bahria Town Islamabad, abbasarshad123@gmail.com.
c: B.Sc. in Civil Engineering, University of Lahore, Islamabad.

Abstract- Green building is also known as a sustainable or high performance building. Various efforts have made by researchers to discover the critical success factors (C-S-Fs) for green building projects (G-B-P) in past few years. However, the most important C-S-Fs need to summarize from the literature review for the successful completion of G-B-P from planning to execution. The overall aim of this research is to explore the suitability of C-S-Fs for G-B-P. The current study is review of previous studies from 2010 to 2020 on important C-S-Fs for G-B-P. In addition, the C-S-Fs are identify for G-B-P by reviewing 57 research articles of different countries. The review results show the popularity of survey and case study in G-B-P related to construction management sector. The essential contributing factors are collected that are corresponded to research approaches in sustainable construction. The outcomes show that the significant attention is gain by the researchers to consider the C-S-Fs for G-B-P. The C-S-Fs of G-B-P are concisely considered by reviewing 27 articles from the total of 57 articles. After that, outcome in form of almost 12 C-S-Fs are reported in current paper. Among all critical success factors, five factors plays an important role in G-B-P for the improvement in sustainable construction. These factors include clear goals and objectives, owner's involvement and commitment, performance of project manager's, effectiveness of project control and planning and cooperation and communication between project members. These commonly identified five C-S-Fs for G-B-P are discuss in detail. Further studies are required for C-S-Fs of G-B-P, which are also suggested in this work.

Keywords- Critical Success Factors, Green Building Projects; Review; Sustainable Construction.

1 INTRODUCTION

Green building is the practice of making structures and using processes that are environmentally responsible and resource effective throughout a buildings life-cycle from arrangement to design, construction, operation, maintenance, renovation and deconstruction. Green building is also known as a sustainable or high performance building. Construction industry is one of the largest user of energy, material resources, and water. As a result the huge amount of waste and pollution produces. In this regard strategies and actions are needed to make construction activities more environmentally sustainable. There are many ways in which the current nature of building construction activity can be controlled and improved to make it less environmentally damaging, without reducing the useful output of construction building activities. Although new technologies such as Building Research Establishment Environmental Assessment Method (BREEAM), Building for Environmental and Economic Sustainability (BEES), Leadership in Energy and Environmental Design (LEED) *etc*. are the key solutions to sustainable developed. G-B provides good performance to environment, i.e. improved energy, air quality and water efficiency, and minimize the environmental pollution. Live or working in G-B environment can lead to healthy and environmental friendly as compared to traditional buildings. With the rising environmental pollution, it is recommended that G-B is the solution of sustainable buildings. The green building projects (G-B-P) are categorized according to the environmental performance like better water efficiency and energy, better air quality of in-door environment, and minimization of air pollutions [1]. Through, the rising universal concern on the global pollutions for G-B-P are being recommended [2]. The construction industry badly impacts the environment throughout the life cycle of a construction from the raw materials transport to sites of construction, operation, processing, repairs and destruction of a building facility [3, 4]. Further than these environmental paybacks which are stated earlier, it is easier and better to work or live in G-B-P rather than traditional method of construction [5]. Moreover, study has discovered the economic benefits of G-B-P from a development perception owed to water savings and energy, reduced cost of mechanical equipment's, reduce consumption of natural resource and material [6, 7]. In addition, the G-B-P industry is still in the preliminary phase by fast growth in specific developing countries. Most probably, the project members have limited knowledge in executing the G-B-P competently without failure.

In past years, focus was about social, environment and economic advantages. Several countries take action to apply a series of G-B-P correlated strategies, as well as compulsory principles, tax concessions and financial incentives, to promote the growth of G-B-P [8-10]. However, delivering G-B-P is necessary, which would need novel technologies, dependable reproduction exploration, friendly environmental materials and complex architectural design [11, 12]. Moreover, organization actions have well known through the C-S-Fs [13]. In this regard, the exact list of C-S-Fs for G-B-P requirements can be recognize for recovering the probabilities of success. The firstly C-S-Fs is innovated by Rockart [14] and it is well-defined as key zones of action where advantageous outcomes are completely essential for a leader to achieve the targets. The literature also explored the efforts in G-B-P area, and three collective themes are identified: (a) definition and scope of G-B; (b) various methods to achieve G-B; and (c) quantification of benefits of G-B [15]. One more investigation was reported and classified in to four parts: G-B-P project delivery and improvements, G-B-P documentations, performance of energy and innovative technologies. Also, the quick-tempered development of G-B-P associated are considered in recent years [16]. In this regard, quantitatively investigation is made for G-B-P field in thirty eight core fields [17]. Therefore, in this study, the critical success factors are identified for ease of project completion, while execution of green building projects.

In this current study, the latest articles from last 10 years are selected for analysis with limited number of critical success factors (C-S-F) from 2010 to 2020. Previous studies on review of green building did not reported the different analysis tools for C-S-F. Therefore, in this paper, a brief review is presented with limited number of C-S-F and tools for analysis of these C-S-Fs are suggested for future work, which is the main contribution of this work.

2 METHODOLOGY

2.1 Identification of journal for success factors

The current research is organize in a way to address studies on C-S-Fs for G-B-P. Frequently, many factors might influence the provision of G-B-P, wide range and departmental level factors [18, 19]. Only project-management-and project interrelated aspects are taken in consideration. Three databases, i.e. Science Direct, Engineering Village, and Scopus are taken into consideration. Keywords for searching include sustainable construction, sustainability in construction projects, critical success factor, green building, environmental effect of building construction and factor effecting sustainability etc. The papers from high quality journals were selected on the basis of journal ranking according to the top most journals of construction management. For summarization of C-S-Fs for G-B-P research articles are categorized. The journal articles were selected accordance with classification list as shown in Figure 1. The twelve journals for research articles include International Journal of Project Management (I-J-P-M), Journal of Construction Engineering and Management (J-C-E-M), Construction Management and Economics (C-M-E), Journal of Management in Engineering (J-M-E), Journal of Civil Engineering and Management (J-C-E-M), Building and Environment (B-E), Engineering Construction and Architectural Management (ECAM), Energy and Buildings (E-B), Habitat international (H-I), Building Research and Information (B-R-I), Journal of Cleaner Production (J-C-P) and Journal of Green building (J-G-B). Afterward that thoughtful check was applied to the study group and a total of 57 research articles are kept given their significance to C-S-Fs of G-B-P. Content collection for C-S-Fs for G-B-P criteria for journal articles are as follows:

- Main concentration on reviewing articles was on G-B-P related to C-S-Fs.
- Only International journal articles publications are considered.
- Investigation of articles consideration especially from 2010 to 2020.

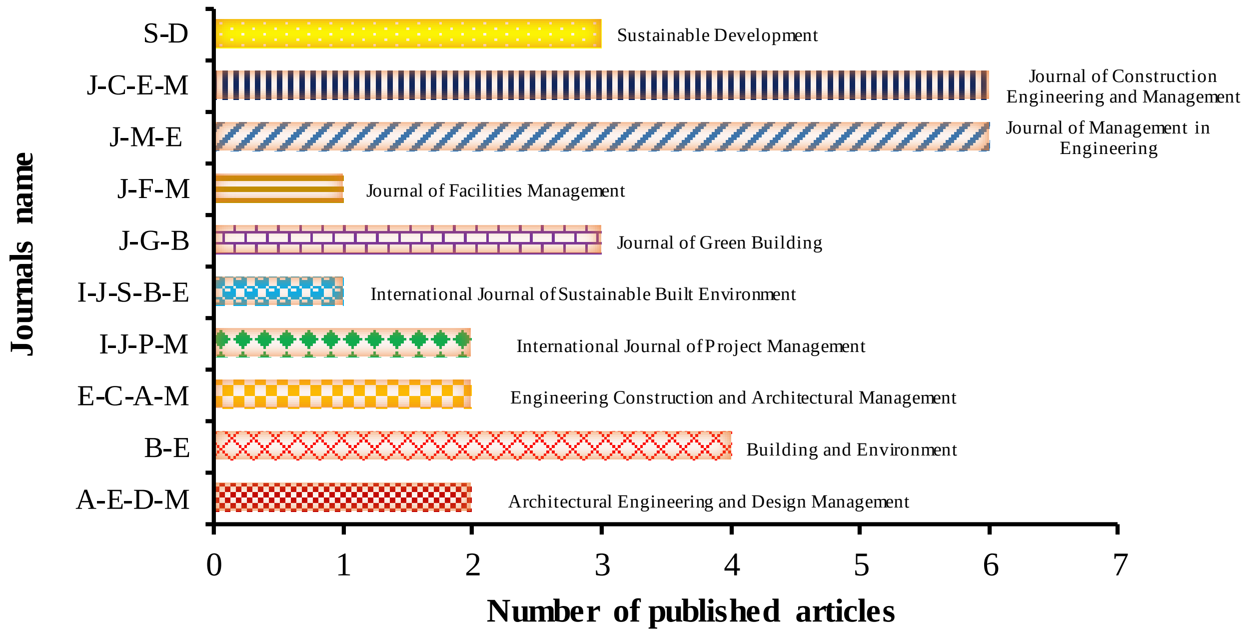


Figure 26. Journals details.

2.2 Papers analysis

The current research is focus on review of publications that are relative to C-S-Fs of G-B projects from the years of 2010 to 2020 judgmentally and thoroughly as shown in Figure 2. The 57 research articles are reviewed for C-S-Fs of G-B projects.

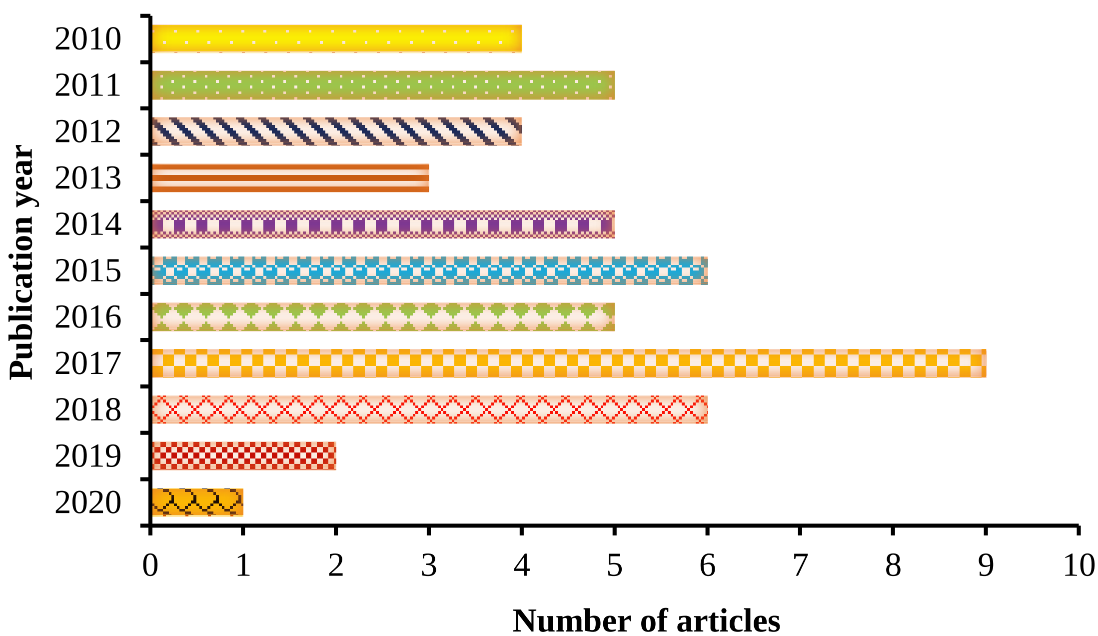


Figure 27. Published articles details.

3 RESULTS AND DISCUSSIONS

3.1 *Analysis outcome*

Analysis outcome for C-S-Fs for G-B-P are shown in Figure 3. The twelve C-S-Fs are reported in current research namely reliability & quality of specification, guide & bench marking systems, effective project planning & control, trust among stakeholders, communication & cooperation between project participants, skilled facilities management team, top management support, workers' experience, awareness & skill level, clear goals & objectives, longer commissioning & tuning periods, policy & regulatory project manager's performance, owner's involvement & commitment [20, 21].

Figure 28. Tree of 12 identify critical success factors from literature

3.2 *Discussions*

. The C-S-Fs of G-B-P are brief investigated by reviewing 27 publications from total of 57 articles as shown in Table 1. After the investigation, 27 articles are found to have these top five critical success factors, which are also mention in Figure 4. The importance of each factor of G-B-P for the duration of the life cycle phase of project, which contain planning and design stage, construction stage and se and maintenance stages are studied. Planning, design, and construction stages discover in 27 articles. Use and maintenance stages found to be in 9 articles. Planning, design, and construction stages has dynamic impact on G-B-P [19, 22]. Use & maintenance stage has limited focus in current study. According to conducted analysis, the top five factors are clear goals and objectives, owner's involvement and commitment, performance of project manager's, effectiveness of project control and planning and cooperation and communication between project members [23, 24]. All these factors are categorize by most reviewed article level, i.e. 8, 9, 9, 11 and 14 times in accordance with 27 research articles, respectively.

Figure 29. Flow chart of five critical success factors for green building

The term "clear objectives and goals" is recognized as level 1 and considered as the first C-S-Fs for G-B-P cited by 8 research articles. Only depending on plainly well-defined project goals and objectives, perfect and complete execution project ideas for entirely upcoming work by all other phases of the project are established. It is understandable that well-defined and flawless goals can decrease the chance of or later orders changing or changes in design which can result inadequacies of cost, delay in schedule and even failure of G-B applications [25]. The second term "commitment and involvement of owner's" are categorized as level 2, accordance with 9 research articles. It is more attention-grabbing to note that the owner's role is more perilous than that of other project sponsors, like project managers, designers and builders.

For understanding it is too easier, that the G-B-P primary cost generally rises with the level of enhanced sustainability and maximum primary costs is the core barricades affecting the G-B-P employment [26]. The third term "project manager's performance" C-S-Fs for G-B-P outcome reported by 9 research articles and also fall in level 3. The project manager is responsible for project management group and manages project deeds and tasks. In the design phase, the leader would involve the whole project management group to bring prepared cost estimates, finalized design, and related documents etc. which is very important for G-B-P design phase [27]. In the construction phase, the project leader is responsible for implementation of sustainable scheme technology for project delivery. The term four "effective project planning and control" C-S-Fs for G-B-P outcome by 11 research articles and also fall in to level 4. It is clear that G-B-P has integrated new materials and technologies that are greatly difficult and tough to implement at the operating phase rather than traditional method. Accordingly, G-B-P easily suffer from schedule interruption, overruns of cost, losses in production and might result in greater damage rate [28]. In this regard, highest-quality of sustainability for planning implementation incorporated into the accomplishment plan of project which might decrease the risks and assure the execution of G-B-P [29]. The term five "communication and cooperation between project participants" outcome is reported by 13 research articles and also reported in level 5. It is very clear that the term five would be the option for minimizing the path barriers to the incorporation of responsive materials for globally, innovative green technologies and model software in G-B-P. [30].

4 ANALYSIS TOOLS

The Analytic network process (ANP) is a common form of the investigative hierarchy method. The technique fuzzy ANP is used to find the complication of the project. Building Information Modeling (BIM) is a combination of digital tools for managing the effectiveness of construction projects for sustainability. A Green Building assessment method is a tool for evaluating either the building is green or not, after this detailed assessment building will be ranked accordingly. The different techniques are used for the analysis of C-S-Fs for the sustainability in construction projects like fuzzy DEMATEL and fuzzy analytic network process (fuzzy ANP) [31]. Analytic Network Process (ANP) method and interpretative structural modelling (ISM) are also employed for analysis of C-S-Fs for G-B-P. Furthermore, comprehensive details of G-B-P are available, like affecting barriers to G-B-P adoption [32], implementation of G-B-P for drivers stimulating [33], assessment methods for G-B [34], building information modeling (BIM) [35], and construction of G-B in economics perspective [36].

Table 20. C-S-Fs for G-B-P from previous studies.

Sr. No.	Authors	Category	No. of articles	Critical success factors	References of articles
1	Robichaud & Anantatmula 2010, Low et al. 2014, Shi et al. 2012, Rasekh & McCarthy 2016, Saleh et al. 2015, Ihuah & Kakulu 2014, Hwang et al. 2017, Mavi & Standing 2018.	Planning & Design, Construction, Use & Maintenance	8	Clear goals and objectives.	[25]. [37]. [22]. [38]. [39]. [40]. [41]. [42]. [31]
2	Hassan et al. 2010, Low et al. 2014, Shi et al. 2012, Korkmaz et al. 2011, Aktas & Ozorhon 2015, Murtagh et al. 2016, Ihuah & Kakulu 2014, Venkataraman & Cheng 2018, Banihashemi 2017.	Planning & Design, Construction, Use & Maintenance	9	Owner's involvement and commitment.	[21]. [37]. [22]. [43]. [44]. [26]. [45]. [41]. [46].
3	Hassan et al. 2010, Shen et al. 2017, Shi et al. 2012, Hwang et al. 2013, Ihuah & Kakulu 2014, Xu et al. 2015, Banihashemi 2017, Sang et al. 2018, Yu et al. 2018, Raouf & Ghamdi 2020.	Planning & Design, & Construction	9	Performance of project managers.	[21]. [47]. [22]. [48]. [41]. [49]. [50]. [51]. [52].
4	Hwang et al. 2016, Hassan et al. 2010, Low et al. 2014, Korkmaz et al. 2011, Rasekh & McCarthy 2016, Hwang et al. 2016, Ihuah & Kakulu 2014, Xu et al. 2011, Xu et al. 2015, Yates 2014, Banihashemi 2017.	Planning & Design, Construction, Use & Maintenance	11	Effectiveness of project control and planning.	[37]. [26]. [39]. [53]. [41]. [54]. [49]. [55]. [50].
5	Robichaud & Anantatmula 2010, Li et al. 2011, Hassan et al. 2010, Shi et al. 2012, Hwang et al. 2015, Korkmaz et al. 2011, Aktas & Ozorhon 2015, Sakr et al. 2011, Rasekh & McCarthy 2016, Saleh et al. 2015, Hwang et al. 2016, Ihuah & Kakulu 2014, Venkataraman & Cheng 2018, Xu et al. 2011.	Planning & Design, Construction, Use & Maintenance	13	Communication and cooperation between project members.	[13]. [21]. [22]. [56]. [44]. [26]. [57]. [39]. [40]. [53]. [41]. [46]. [54].

5 CONCLUSION

The current work is critical review of the articles from 2010 to 2020. A total of 27 published articles related to C-S-Fs of G-B-P were specifically considered from 57 articles. After the investigation, 27 articles are found to have top five critical success factors, which plays an important role in G-B-P for the improvement in sustainable construction. The top five aspects are describe as clear goals and objectives, owner's involvement and commitment, performance of project manager's, effectiveness of project control and planning and cooperation and communication between project members. The detailed investigation exhibited that the maximum interrelated articles were published in different journals namely International Journal of Project Management (I-J-P-M), Journal of Construction Engineering and Management (J-C-E-M), Construction Management and Economics (C-M-E), Journal of Management in Engineering (J-M-E), Journal of Civil Engineering and Management (J-C-E-M), Building and Environment (B-E), Engineering Construction and Architectural Management (ECAM), Energy and Buildings (E-B), Habitat international (H-I), Building Research and Information (B-R-I), Journal of cleaner production (J-C-P) and Journal of Green building (J-G-B). The evaluation of factor is done based on the same factors considered by many studies in planning, design, construction and maintained phase. Also, the identified 12 C-S-Fs for G-B-P were reported by reviewing 27 research articles and 5 C-S-Fs are briefly discussed in current research. The most important phases were considered, i.e. construction and design phase, but more studies are taken at the usage and maintenance phase. It is found that the interrelated project sponsors, contractors and owners are the major contributors accountable to the C-S-Fs in G-B-P. The different tools for analysis of these C-S-F are also discussed.

6 FUTURE FINDINGS

The academic focus on C-S-Fs for G-B-P are more since 2010 from previous research. However, the practical implementation of these factors are still lacks. Further investigation should be carried out on following aspects:

1. Comparison between different analysis methods should be consider for validity of top common success factors.
2. More investigation are necessary on C-S-F for all building types.
3. There is need to develop relations between the C-S-Fs and important phase from planning to execution.
4. More studies is required on C-S-Fs of different project like China Pakistan Economic corridor (CPEC).

ACKNOWLEDGMENT

The authors would like to thank Dr. Syed Shuja Safdar Gardazi who helped throughout the research work for his kind support and guidance.

REFERENCES

[1] J. Laustsen, "Energy efficiency requirements in building codes, energy efficiency policies for new buildings. IEA Information Paper," *Support of the G8 Plan of Action*, 2008.

[2] A. Adler, J. Armstrong, S. Fuller, M. Kalin, A. Karolides, J. Macaluso, *et al.*, "Green building: Project planning and cost estimating," *Kingston, Massachusetts*, 2006.

[3] P. X. Zou and P. Couani, "Managing risks in green building supply chain," *Architectural Engineering and Design Management*, vol. 8, pp. 143-158, 2012.

[4] S. P. Low, S. Gao, and L. L. G. Teo, "Gap analysis of green features in condominiums between potential homeowners and real estate agents," *Facilities*, 2016.

[5] W. L. Paul and P. A. Taylor, "A comparison of occupant comfort and satisfaction between a green building and a conventional building," *Building and environment*, vol. 43, pp. 1858-1870, 2008.

[6] S. D. Johnson, "The economic case for "High performance buildings"," *Corporate Environmental Strategy*, vol. 7, pp. 350-361, 2000.

[7] P. v. Paumgartten, "The business case for high performance green buildings: Sustainability and its financial impact," *Journal of Facilities Management*, vol. 2, pp. 26-34, 2003.

[8] J. Y. Liu, S. P. Low, and X. He, "Green practices in the Chinese building industry: drivers and impediments," *Journal of Technology Management in China*, 2012.

[9] N. Wang, Y.-C. Chang, and C. Nunn, "Lifecycle assessment for sustainable design options of a commercial building in Shanghai," *Building and Environment*, vol. 45, pp. 1415-1421, 2010.

[10] S. P. Low, J. Y. Liu, and P. Wu, "Sustainable facilities," *Facilities*, 2009.

[11] M. H. Pulaski and M. J. Horman, "Continuous value enhancement process," *Journal of Construction Engineering and Management*, vol. 131, pp. 1274-1282, 2005.

[12] A. O. Olanipekun, B. Xia, C. Hon, and A. Darko, "Effect of motivation and owner commitment on the delivery performance of green building projects," *Journal of Management in Engineering,* vol. 34, p. 04017039, 2018.
[13] Y. Y. Li, P.-H. Chen, D. A. S. Chew, C. C. Teo, and R. G. Ding, "Critical project management factors of AEC firms for delivering green building projects in Singapore," *Journal of construction engineering and management,* vol. 137, pp. 1153-1163, 2011.
[14] J. F. Rockart, "The changing role of the information systems executive: a critical success factors perspective," 1980.
[15] J. Zuo and Z.-Y. Zhao, "Green building research–current status and future agenda: A review," *Renewable and sustainable energy reviews,* vol. 30, pp. 271-281, 2014.
[16] S. Korkmaz, D. Riley, and M. Horman, "Piloting evaluation metrics for sustainable high-performance building project delivery," *Journal of Construction Engineering and Management,* vol. 136, pp. 877-885, 2010.
[17] B. G. Hwang and L. P. Leong, "Comparison of schedule delay and causal factors between traditional and green construction projects," *Technological and Economic Development of Economy,* vol. 19, pp. 310-330, 2013.
[18] L. Zhang, J. Wu, and H. Liu, "Turning green into gold: A review on the economics of green buildings," *Journal of cleaner production,* vol. 172, pp. 2234-2245, 2018.
[19] V. Gomes and M. G. da Silva, "Exploring sustainable construction: implications from Latin America," *Building Research & Information,* vol. 33, pp. 428-440, 2005.
[20] N. Wang, S. Yao, G. Wu, and X. Chen, "The role of project management in organisational sustainable growth of technology-based firms," *Technology in Society,* vol. 51, pp. 124-132, 2017.
[21] A. A. Bakar, A. A. Razak, S. Abdullah, A. Awang, and V. Perumal, "Critical success factors for sustainable housing: a framework from the project management view," *Asian journal of management research,* vol. 1, pp. 66-80, 2010.
[22] N. Wang, K. Wei, and H. Sun, "Whole life project management approach to sustainability," *Journal of Management in Engineering,* vol. 30, pp. 246-255, 2014.
[23] Y. H. Ahn and A. R. Pearce, "Green construction: Contractor experiences, expectations, and perceptions," *Journal of Green Building,* vol. 2, pp. 106-122, 2007.
[24] M. M. Bilec, R. J. Ries, K. L. Needy, M. Gokhan, A. F. Phelps, E. Enache-Pommer, *et al.*, "Analysis of the design process of green children's hospitals: Focus on process modeling and lessons learned," *Journal of Green Building,* vol. 4, pp. 121-134, 2009.
[25] L. B. Robichaud and V. S. Anantatmula, "Greening project management practices for sustainable construction," *Journal of management in engineering,* vol. 27, pp. 48-57, 2011.
[26] Y. Kang, C. Kim, H. Son, S. Lee, and C. Limsawasd, "Comparison of preproject planning for green and conventional buildings," *Journal of Construction Engineering and Management,* vol. 139, p. 04013018, 2013.
[27] K. Y. Mok, G. Q. Shen, and J. Yang, "Stakeholder management studies in mega construction projects: A review and future directions," *International Journal of Project Management,* vol. 33, pp. 446-457, 2015.
[28] S. Korkmaz, D. Riley, and M. Horman, "Assessing project delivery for sustainable, high-performance buildings through mixed methods," *Architectural Engineering and Design Management,* vol. 7, pp. 266-274, 2011.
[29] B. R. Fortunato III, M. R. Hallowell, M. Behm, and K. Dewlaney, "Identification of safety risks for high-performance sustainable construction projects," *Journal of Construction Engineering and Management,* vol. 138, pp. 499-508, 2012.
[30] S. Bond, "Lessons from the leaders of green designed commercial buildings in Australia," *Pacific Rim Property Research Journal,* vol. 16, pp. 314-338, 2010.
[31] R. K. Mavi and C. Standing, "Critical success factors of sustainable project management in construction: A fuzzy DEMATEL-ANP approach," *Journal of cleaner production,* vol. 194, pp. 751-765, 2018.
[32] A. Darko, A. P. Chan, X. Huo, and D.-G. Owusu-Manu, "A scientometric analysis and visualization of global green building research," *Building and Environment,* vol. 149, pp. 501-511, 2019.
[33] A. Darko and A. P. Chan, "Review of barriers to green building adoption," *Sustainable Development,* vol. 25, pp. 167-179, 2017.
[34] Y. Li, X. Chen, X. Wang, Y. Xu, and P.-H. Chen, "A review of studies on green building assessment methods by comparative analysis," *Energy and Buildings,* vol. 146, pp. 152-159, 2017.
[35] A. Darko, C. Zhang, and A. P. Chan, "Drivers for green building: A review of empirical studies," *Habitat international,* vol. 60, pp. 34-49, 2017.
[36] Y. Lu, Z. Wu, R. Chang, and Y. Li, "Building Information Modeling (BIM) for green buildings: A critical review and future directions," *Automation in Construction,* vol. 83, pp. 134-148, 2017.
[37] D. K. Ahadzie, N. A. Ankrah, S. P. Low, S. Gao, and W. L. Tay, "Comparative study of project management and critical success factors of greening new and existing buildings in Singapore," *Structural Survey,* 2014.

[38] Q. Shi, J. Zuo, and G. Zillante, "Exploring the management of sustainable construction at the programme level: a Chinese case study," *Construction Management and Economics,* vol. 30, pp. 425-440, 2012.
[39] H. Rasekh and T. J. McCarthy, "Delivering sustainable building projects–challenges, reality and success," *Journal of Green Building,* vol. 11, pp. 143-161, 2016.
[40] A. A. Saleh, A. H. Mohammed, and M. N. Abdullah, "Exploring critical success factors of energy management for sustainable building in Malaysian University," *Jurnal Teknologi,* vol. 73, 2015.
[41] P. W. Ihuah, I. I. Kakulu, and D. Eaton, "A review of Critical Project Management Success Factors (CPMSF) for sustainable social housing in Nigeria," *International Journal of Sustainable Built Environment,* vol. 3, pp. 62-71, 2014.
[42] B.-G. Hwang, L. Zhu, and J. S. H. Tan, "Identifying critical success factors for green business parks: Case study of Singapore," *Journal of Management in Engineering,* vol. 33, p. 04017023, 2017.
[43] Y. Li, H. Song, P. Sang, P.-H. Chen, and X. Liu, "Review of Critical Success Factors (CSFs) for green building projects," *Building and Environment,* 2019.
[44] B.-G. Hwang, X. Zhao, and L. L. G. Tan, "Green building projects: Schedule performance, influential factors and solutions," *Engineering, Construction and Architectural Management,* 2015.
[45] B. Aktas and B. Ozorhon, "Green building certification process of existing buildings in developing countries: cases from Turkey," *Journal of Management in Engineering,* vol. 31, p. 05015002, 2015.
[46] V. Venkataraman and J. C. Cheng, "Critical success and failure factors for managing green building projects," *Journal of Architectural Engineering,* vol. 24, p. 04018025, 2018.
[47] W. Shen, W. Tang, A. Siripanan, Z. Lei, C. F. Duffield, D. Wilson, *et al.*, "Critical success factors in thailand′ s green building industry," *Journal of Asian Architecture and Building Engineering,* vol. 16, pp. 317-324, 2017.
[48] A. O. Olanipekun, B. Xia, and H.-T. Nguyen, "Motivation and owner commitment for improving the delivery performance of green building projects: A research framework," *Procedia engineering,* vol. 180, pp. 71-81, 2017.
[49] P. Xu, E. H. Chan, H. J. Visscher, X. Zhang, and Z. Wu, "Sustainable building energy efficiency retrofit for hotel buildings using EPC mechanism in China: analytic Network Process (ANP) approach," *Journal of Cleaner Production,* vol. 107, pp. 378-388, 2015.
[50] S. Banihashemi, M. R. Hosseini, H. Golizadeh, and S. Sankaran, "Critical success factors (CSFs) for integration of sustainability into construction project management practices in developing countries," *International Journal of Project Management,* vol. 35, pp. 1103-1119, 2017.
[51] P. Sang, J. Liu, L. Zhang, L. Zheng, H. Yao, and Y. Wang, "Effects of project manager competency on green construction performance: the Chinese context," *Sustainability,* vol. 10, p. 3406, 2018.
[52] A. M. Raouf and S. G. Al-Ghamdi, "Managerial Practitioners' Perspectives on Quality Performance of Green-Building Projects," *Buildings,* vol. 10, p. 71, 2020.
[53] B. Hwang, M. Shan, and E. Tan, "Investigating reworks in green building construction projects: Magnitude, influential factors, and solutions," *International Journal of Environmental Research,* vol. 10, pp. 499-510, 2016.
[54] P. Xu, E. H.-W. Chan, and Q. K. Qian, "Success factors of energy performance contracting (EPC) for sustainable building energy efficiency retrofit (BEER) of hotel buildings in China," *Energy policy,* vol. 39, pp. 7389-7398, 2011.
[55] J. Yates, "Design and construction for sustainable industrial construction," *Journal of construction engineering and management,* vol. 140, p. B4014005, 2014.
[56] L. Zhang and J. He, "Critical factors affecting tacit-knowledge sharing within the integrated project team," *Journal of Management in Engineering,* vol. 32, p. 04015045, 2016.
[57] D. Sakr, L. Baas, S. El-Haggar, and D. Huisingh, "Critical success and limiting factors for eco-industrial parks: global trends and Egyptian context," *Journal of Cleaner Production,* vol. 19, pp. 1158-1169, 2011.

SUSTAINABLE CONSTRUCTION AND DEMOLISHING WASTE MANAGEMENT: A CASE STUDY IN PAKISTAN

[a] Fahad Amin, [b] Aown Muhammad [c] Fakhr-e-Alam
a: Department of Civil Engineering, COMSATS University Islamabad (Abbottabad campus), fahadamin1995@gmail.com
b: Department of Civil Engineering, University of Engineering and Technology Taxila , makhdoomaown@gmail.com
c: Department of Civil Engineering, COMSATS University Islamabad (Abbottabad campus), fakhrkhan57@outlook.com

Abstract- Construction and Demolition waste management (CDWM) is an important topic nowadays as the world is moving towards more sustainable development. The social, economic, and environmental objectives will take into consideration as human health, safety, and quality of life is the main concern without compromising the sustainable future. In this paper, C&D waste is categorized, barriers against CDWM from different countries are analyzed and relate with CDWM in Pakistan. A case study is conducted in which a CDWM model is used to, minimize waste generation in the first place i.e. waste process management is implemented, reuse of demolished material. Suggestions are made by keeping the objectives of waste management in mind. As sustainability aims are crucial in CDWM, findings will help create some effective models of CDWM in Pakistan's construction industry.

Keywords- Waste Management Barriers, Construction And Demolition Waste Management, CDWM In Pakistan, Sustainability

1 INTRODUCTION

Construction waste arise environmental problems so, it is important to develop new and effective strategies. Knowledge and awareness about waste are necessary to acknowledge in order to save the environment. The construction industry is the main source of solid waste all over the globe [1].40% of the total municipal waste in china is from construction industries. It is impossible to avoid waste generation in construction [2]. Although, there are different methods introduced in the past decade that minimize the waste to minimal level up to 1% i.e. DfMA and MiC. However, these methods are complex to understand. The waste has severe effects on the socio-environmental factors of sustainability, as the population increases results increase in pollution in different forms i.e. greenhouse gasses emission, water pollution, and uneven and unmanaged resources consumption [3] [4]. Human health and safety is the main concern of the based on sustainability factors. So, it is necessary to develop a sustainability model that assesses the construction and demolition waste management. Evaluation of the CDWM system becomes a crucial problem [5].

This paper aims to introduce certain KPIs to control the waste at different stages of the project for different materials. Moreover, overall project success with respect to wastage needs certain KPI. This research will also encourage researchers from Pakistan to work on barriers against sustainable construction and sustainable development.

2 RESEARCH SIGNIFICANCE

This research will open a new area to develop the new CDWM models that are suitable for Pakistan's current condition. How can demolishing material be reuse and dispose of?

This paper will also provide a foundation for the researcher to work on barriers in implementation of new CDWM models in Pakistan.

3 RESEARCH METHODOLOGY

Pakistan, is one of the developing countries in the world, is facing many problems regarding population increase, urbanization, land scarcity, waste management, public health, environment, etc. given the waste management area priority over others can solve many of the problems. Most of the municipal waste comes from the construction industry

Within the cities, it is complex to sort out the construction waste into reuse, recycle, and dispose of small projects due to lack of awareness and knowledge about sustainability. In large projects, the construction waste is not sorted out as it has to. Most contractors and clients in Pakistan that work privately are not well educated and well aware of waste management. Moreover, the government did not put a check on local and private contractors or builders that causes a lot of construction waste generation.

In this paper, Hong Kong's construction and demolishing waste management strategies are studied, barriers, challenges, and suggestions are made to try to implement on Pakistan's waste management strategy to build a new and effective CDWM model.

A case study is done to show that how this CDWM model effectively implemented on construction project named SANA MALL in Bahria Enclave Islamabad Pakistan.

4 CONSTRUCTION WASTE MATERIAL

Construction waste is a by-product generated during the construction of civil engineering projects, demolishing of existing or renovation of old projects e.g. steel, concrete, blocks, bricks, wood, road waste, and many more [6] [7]. The construction waste is differentiated in inert and non-inert type. The non-inert materials are that are not suitable for land reclamation so they usually disposed of. The inert waste materials usually include steel, concrete type materials that are used to land reclamation. More than 80% of the construction waste material is inert [6] [8]. Concrete and asphalt can be used as engineering fill for site formation of the base before the plain concrete.

The C&D waste is categorize in five different categories. These types and their source of generation is given below in table 1 [9].

Table 21- Waste generation materials and their sources

Description	Waste generating sources
Concrete	Leakage in formwork
	Demolishing
Cement	Plastering
	Chiseling
	Over order
Blocks	Deformation during working
	Deformation during transportation
Timber	Leftover
	Deformation during working
Tiles	Deformation during working
	Deformation during transportation
	Design changes

In 1998, the government of Hong Kong establishes the committee on construction waste reduction comprising engineers, contractors, developers, specialists from the community, and government officials. The main focus of the construction waste reduction committee was managing the public landfills, introducing construction technologies, standards, and specifications and training, awareness regarding construction waste [10].

Currently, all the government work contractors need to prepare a waste management strategy and implement it according to specifications by the construction waste reduction committee. Certainly, the contractors need to sort out waste into different categories so that wastes go to the appropriate dumping site [1].

The Hong Kong government also introduces a "pay for safety and environment scheme" that helps contractors with financial incentives provoking them to implement the waste management and environmental improvement plans. In 2005, the government took the initiative that charge contractors on dumping waste at landfills. This as well compels the contractor to sort out the waste for reuse or recycling.

5 MAIN METHODS TO ASSESS CDWM PERFORMANCE

There are three methods to assess the CDWM performance upon which in this paper only the sustainability based methods will be studied; others are system thinking based method and life cycle thinking base method [11].

5.1 *Sustainability Based Method*

In CDWM sustainability have greater impact. Sustainability based methods are further divided into three types i.e. environmental, economic and social Sustainability based methods. A project will be in sustainable success if all three aspects are achieved.

An environmental sustainable method gives ecological activities priority irrespective of the other two pillars of sustainability. Matter of fact, all three methods are connected in certain ways depending on project nature i.e. Socio-economic, socio-environmental, and environmental-economic factors are being analyzed and implemented [12].

Almost 90800 projects are built on green construction methods that have all social, economic, and environmental aspects as 80 million tons of less waste generated and 41% less energy consumption. However, greenhouse construction projects have 4% more value in real estate than others. Green construction is a new method that more sustainable. For sustainable development, it is important that all three pillars of sustainability are touched which makes green construction more reliable.

6 BARRIERS AND SUGGESTIONS ON CONSTRUCTION AND DEMOLISHING WASTE MANAGEMENT

Based on previous studies, discussion and interviews on construction waste management in Hong Kong, this paper project the challenges and suggestions of construction industry of Hong Kong to Pakistan's construction industry. Construction industry and particularly waste management in both countries are much different. Topography, culture and many other variables that differentiate one's industry from another. Hong Kong on the other hand has much better condition regarding to sustainability aspects. Following are the suggestions and barrier in construction and demolition waste management in Pakistan

- For both Private and governmental contractors it is necessary to get a Pakistan engineering council license, so if contractor dump waste into unauthorized place there should be necessary action taken against them.
- Every contractor should submit their waste management plan to the municipal beside the construction approval document. Otherwise, the municipal have the authority to stop the work and fine them.
- Contractors should be charged against the dumping waste weight. This will encourage contractors to recycle, reuse waste, or use some other strategy before disposal.
- The government should make a law regarding construction waste management. Incentives should be given to contractors that fully manage the waste plan.
- Lack of technologies and new strategies is one of the main reasons for waste generation in the first place. So contractors should be well aware of new ways of construction that helps towards sustainable future

- Construction management is a very important skill. As more than one construction activities happen at the same time and many subcontractors' involve in this process. So, it is important for the construction manager to put strict checks on them against the time schedule and waste generation.
- In Pakistan's construction industry lack of site-supervision is a big issue. A usually unskilled and uneducated person found to be a site engineer that has practically no knowledge about waste management.
- One of the main barriers in Pakistan's construction industry is that contractors don't have enough knowledge about waste management. They should be educated about new and easy ways of CDWM.
- Tight time schedules are one of the causes that waste is not treated as it should be.
- Profit oriented stakeholders don't want to spend capital on waste management because of zero law reinforcement.
- Using CDW with lime or cement, low cost bricks with excellent physical properties.
- Suitable waste can be used as backfilling can be considered low quality recovery, as it replaces soil that have high environmental impact from its production.

7 KEY PERFORMANCE INDICATOR

Key performance indicators KPI are the main elements to measure progress of any project towards pre-defined goals and used critically in the decision-making process regarding any activity in the project. KPI's in waste management have economic value i.e. it gives indications about waste generation during the work done. Exceeding value of KPI tells about more waste generation and helps the construction manager to take proper actions. These KPIs vary from activity to activity, stage of the project, and organizational scope of work. In construction waste management the KPI's used for different activities are given bellow

Table 22 - KPI's for waste management

Activities	**KPI**	**KPI Limit (A)**	**Actual value (B)**	**KPI value (B/A)**	**Remarks**
Masonry	MSR	5%	7.2%	1.44	Not favorable
Plaster	PLT	2%	6.8%	3.4	Not favorable
Concrete	CTR	5%	3.7%	0.74	Favorable
Steel rebar	STL	5%	8.9%	1.78	Not Favorable

KPI's are important to control the project in different aspects. In waste management, above KPI indicates projects performance at any stage. At the end of project a general KPI's introduced in order to get one single figure that represent all the wastage during the activities.

8 CASE STUDIES

Sana mall is located in Bahria Enclave Islamabad. Due to change in architectural drawings after the completion of the grey structure results in demolishing of concrete and block masonry. Sana mall has 3 stories: basement, ground floor, and first floor. The total area of concrete to demolish was 10,000 square fit. 400 tons of concrete was demolished and transported into different sites. The 45 tons of steel later used in making drains. Transportation of wastage was a difficult task. Keeping all three aspects of sustainability in mind following are the KPI are used to assess the performance of CDWM.

Table 23- Demolished materials and respective costs

Description	Quantity	Amount (Rs)	Demolishing cost (Rs)	Transportation cost (Rs)
Concrete	10,000 cft.	4.5 million	12.5 million	0.9 million
Blocks	22000 sq. ft.	0.77 million	0.11 million	0.05 million
Steel	45 tons	0.292 million	0.1 million	0.05 million
Plaster	44000 sq. ft.	1.1 million	0.05 million	0.02 million
Total costs		**6.662 million**	**12.75 million**	**1.02 million**

The statistics shows that demolishing cost is greater than the actual construction cost. The KPI that was introduced have the economical factor i.e. total wastage used should be 95% of the total.

Table 24- Key Performance Indicators for reuse of demolished materials

Description of KPI	Material against KPI	Usage Location	Actual demolished material	Actual demolished waste usage	Expected demolished waste usage	Variance
STL	Steel	Drains Reinforcement	100	95%	97%	2%
CRT	Concrete	Foundation for walk ways	100	75%	96%	21%
BLK	Blocks	Foundation for walk ways	100	100%	100%	0%
PLT	Plaster	Dumped	100	100%	100%	0%

Almost all the KPIs show that due to demolishing, the project's wastage has good environmental and economic aspects. The excess material later disposed of in landfills. Demolished material has economic and environmental benefits; everything is used in different specific activities. In the walkway, a lot less new material used due to demolished concrete and block filling, steel is used in drains that result in saving huge amounts of capital, also less consumption of new resources that have a positive impact on the environment.

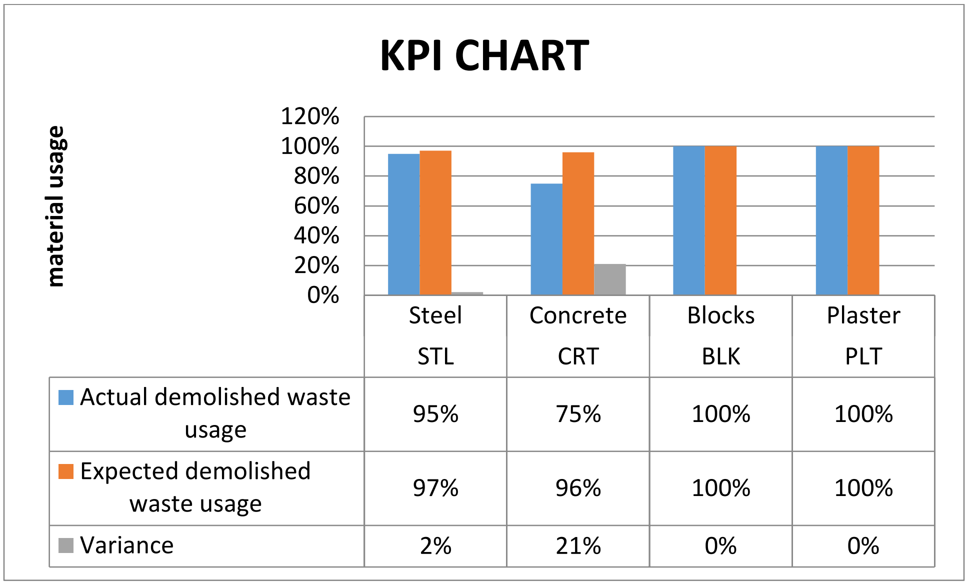


Figure 30: CDWM KPI's performance

9 PRACTICAL IMPLEMENTATION

The KPIs will help contractors to understand earned value from construction and demolishing waste materials. It is easy to implement all C&DW strategies on-site e.g. the main component in CDW is concrete which after crushing used as a sub-base in foundations [13]. It is very important to make new strategies regarding CDW because Pakistan is facing a bigger problem related to demolishing waste as more buildings already crossed their designed life span that will cause the creation of huge demolished materials. So, to sustainable development, it is necessary to reduce construction waste and use demolished waste wisely and sustainably.

10 CONCLUSION

This paper analyzes the current challenges to Construction and demolishing waste management in Pakistan by analyzing Hong Kong's waste management barriers. Suggestions are given in an effort towards better future planning. Lack of education and awareness in the construction industry in Pakistan: the country with a fast-growing population causes a huge and unmanaged consumption of resources results in land scarcity both for new projects and material waste landfills. The government should take initiative towards green construction as Pakistan is facing many issues related to energy, water, and climate change. However, without the participation of Architects, engineers, and contractors, all initiatives would be ineffective. No doubt, minimizing construction and demolishing waste management will be a new area of research in Pakistan.

The government of Pakistan needs to evaluate its waste management strategies. Hong Kong is a city with a relatively small area than the whole country. However, the District Municipal authorities in Pakistan have a hold on a specific small area that makes the implementation of the above-discussed CDWM system easy. A sustainable future for the next generation would be our main concern. The case study in this paper will help contractors to pay some attention to waste that it could be useful in different ways and as it has economic value.

REFERENCES

[1] Yu T.W. and Ng L.H. Poon C.S., "On site sorting of construction and demolishing waste in Hong Kong ," *Resources, Conservation and Recycling* , 2001.

[2] Shen L. Y., Hao J.L and Lu W.S. Yuan H. P., "A model for cost benefit analysis of construction and demolition waste management throughout the waste chain," *Resources, Conservation and Recycling*, 2010.

[3] Wang Y.F., Zou P.X.W. Ding Z.K., "An agent based envirnomental impact assesssment of building demolishion waste management: conventional versus green management," *Cleaning Procedure*, 2016.

[4] Yu A.T.W., Wong A., Yip R. Poon C.S., "Quantifying the impact of construction waste charging scheme on construction waste management in Hong Kong," *J. Construction, Engineering Management*, 2013.

[5] Yuan H.P., "Key indicators for assessing the effectiveness of waste management in construction projects," *Ecological Indicators*, 2013.

[6] Poon C.S., and Chiang Y.H. Jaillion L., "Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong," *Waste Management* , 2009.

[7] Tam W.Y.V., Tam C.M. and Drew D.S. Shen L.Y., "Mapping approach for examining waste management in construction site," *Journal of Construction, Engineering and Management* , 2004.

[8] Tam W.V.Y. and Li C.Y. Shen L.Y., "Benifit analysis on replacing in situ concreting with precast slab for temporary construction works in pursuing sustainable construction practice," *Resource, Conservation and Recycling*, 2009.

[9] Kang X.P., Shen L.Y. and Tam W.Y.V. Wang J.Y., "Reaserch on management measures for reducing construction waste," *Architecture Technology*, 2004.

[10] Hills M.J. and Huang T. Hao J.L., "Difficulties and challenges of managing construction and demolishing waste in Hong Kong," in *Proceedings of Third Structural Engineering and Construcction Conference*, Shunan, Japan, 2005.

[11] Jian Zuo, Hongping Yuan. Huanyu Wu, "A review of performance assessment methods for construction and demolishing waste management ," *Resources, Conservation and Recycling* , 2019.

[12] Jian Zuo, Hongping Yuan, George Zillante Huanyu Wua, "A review of performance assessment methods for construction and demolition waste management," *Resources, Conservation and Recycling*, 2019.

[13] Beijia Huang, Li feng Cui Muhammad Shahzad Aslam, "Review of construction and demolition waste management in China and USA," *Journal of Environmental Management*, 2020.

SUSTAINABILITY ASSESSMENT OF CONSTRUCTION PROJECTS IN PAKISTAN AND GEO-SAT

[a] Faisal Raza
a: NUST Institute of Civil Engineering (NICE), National University of Sciences and Technology (NUST),
email: faysalraxa@gmail.com

Abstract- Sustainability is a philosophy focused on supply and demand considering current generations as well as potential ones. Economy, environment, engineering, and equity (social) are the four foundations of Sustainable Development (SD). The second-largest industry in Pakistan is construction (after agriculture). To evaluate current practices and recommendations for the future, an assessment of the sustainability activities carried out in this sector is required. 37 of 76 generic indicators of Environmental Geotechnics Indicators (EGI) were used for the appraisal of civil engineering ventures in Pakistan. Compared with the most viable options recommended for achieving SD, the findings showed very poor performance. The results also showed the lack of a dedicated sustainability assessment tool for geotechnics, thereby, suggesting an urgent need for the development of one such tool. This paper also presents a framework for the new tool called as Geotechnical Sustainability Assessment Tool (Geo-SAT).

Keywords- Framework, Geotechnical Sustainability Assessment Tool, Impact, Sustainability

1 INTRODUCTION

As per the Brundtland Commission report [1], Sustainable Development (SD) can be defined as "the development that meets the needs of the present without compromising the ability of future generations to meet their needs". The United Nations took decisions to ensure SD through a set of 17 SD Goals with 170 targets [2].

Civil engineering contributes to about 40% consumption of natural resources like gravel, sand, and stone annually thereby contributing most to the global changes and challenges [3]. Construction is the second-largest sector in economic development after agriculture in Pakistan contributing to more than 35% of direct or indirect employment [4]. The activities of this sector, therefore, need assessment. Several sustainability assessment tools are available such as Building Research Establishment Environmental Assessment Method (BREEAM) [5], Leadership in Energy and Environmental Design (LEED) [6], Environmental and Whole Life Cost Estimating Tool (ENVEST 2) [7], SPeAR [8] and EnVision [9]. These tools cannot be applied to geotechnical engineering that shows that geotechnics lacks a dedicated sustainability assessment tool [10]. It is also worth mentioning that no assessment of the construction industry in Pakistan has been carried out previously.

This paper presents the sustainability assessment of the construction sector of Pakistan and a framework for the assessment of geotechnical projects, encompassing the 4 Es (Engineering, Economic, Equity i.e. Social and Environmental) of sustainability as proposed by Basu et al. [11], shown in Figure 31. The new tool is termed as Geo-SAT (Geotechnical Sustainability Assessment Tool) which will serve as a potential code of sustainability for geotechnical projects.

2 METHODOLOGY

2.1 Sustainability Assessment of Construction Projects in Pakistan

All the tools mentioned in section 1 are project-specific and therefore cannot be used to assess the construction industry as a whole. Therefore, the generic indicators developed by Jefferson et al. [12] were used to carry out this assessment. 37 of 76 indicators were selected for this purpose as shown in Table 26. The assessment was carried out using a questionnaire distributed countrywide and responded by civil engineering professionals having worked as at least Project Managers.

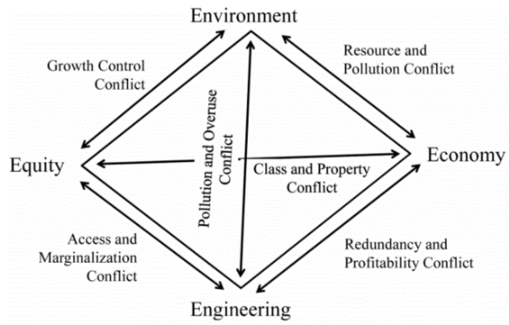


Figure 31: 4 Es of Sustainability [11]

This questionnaire was divided into two main sections i.e. Demographic information and sustainability assessment further divided into stages based on construction activities i.e. Feasibility, Design, Award and Mobilization, Construction, De-Mobilization and Monitoring, and Long-Term. Each stage was assessed using indicators measuring the impact on sustainability on a scale of 1 (detrimental/harmful) to 5 (significantly improved), as shown in Table 25 and Table 26. An effort was also made to check if any sustainability assessment technique is used in Pakistan.

2.2 *Development of a Sustainability Assessment Tool for Geotechnical Projects*

To develop a new tool specific to geotechnical projects, a thorough review focusing on understanding the technical dynamics of geotechnics, sustainability, and existing assessment tools used in construction industry, was carried out. The past and current practices followed, and the recommendations of researchers to achieve SD in line with the goals set by the United Nations were considered for the development of indicators along with a reliable and consistent scale.

3 RESULTS OF SURVEY

Cronbach's alpha test showed excellent reliability with a value of 0.931. The respondents' details and descriptive results of the survey are given below:

3.1 *Respondents*

A total of 66 responses across the country were collected. 62.12% of the firms were aged 20 and above. The firms belonged to different sectors such as government (15.15%), private (72.73%), and others (12.12%) and offering different services such as design (9.09%), construction (51.52%), and consultancy (39.39%). 72.73% of the total firms were involved in the feasibility stage, 54.44% in the design stage, 72.73% in award and mobilization activities, 84.85% in construction activities, 46.97% in de-mobilization activities and 51.52% of the firms carried out monitoring activities.

3.2 *Results of the Survey*

The percentages of firms responding to each indicator as per the scale developed by Jefferson et al. [12] for Environmental Geotechnics Indicators (a sample scale for some indicators shown in Table 25) are given in Table 26.

Table 25: A sample of scale developed by Jefferson et. al [12]

Indicator	**Impact on Sustainability**				
	Detrimental or Harmful (1)	**Reduced (2)**	**Neutral (3)**	**Improved (4)**	**Significantly Improved (5)**
Sustainability Policy	Actively avoids	Passively avoids	No policy	Passively promotes	Actively promotes
Percentage of site investigation costs	< 0.5%	0.5% - 1.0%	1.0% – 3.0%	3.0% - 4.0%	> 4.0%
Types of Tests	None	Simple on-site field tests	Lab tests	Field tests	Lab and field

Table 26-Summary of Questionnaire Results

Indicator	Impact on Sustainability				
	(1)	(2)	(3)	(4)	(5)
Feasibility Stage					
Sustainability Policy	6.25%	8.33%	50%	20.83%	14.58%
Community Consultation Plan	4.17%	47.92%	47.92%	-	-
Percentage of site investigation costs	25%	25%	25%	18.75%	6.25%
Types of Tests	4.17%	2.08%	8.33%	10.42%	75%
Design Stage					
Land Use	11.11%	11.11%	47.22%	16.67%	13.89%
Quantified Risk Assessment (QRA)	44.44%	30.56%	13.89%	5.56%	5.56%
Risk Management Plan (RMP)	38.89%	27.78%	16.67%	8.33%	8.33%
Health and Safety (H&S) Plan	25%	22.22%	36.11%	5.56%	11.11%
Life Cycle Assessment (LCA)	41.67%	11.11%	41.67%	5.56%	-
Supplies from sustainable/recyclable resources	80.56%	16.67%	2.78%	-	-
Award and Mobilization Stage					
Type of Procurements	41.67%	25%	16.67%	8.33%	8.33%
ISO-14001 Accreditation	81.25%	18.75%	-	-	-
Nuisance notices served	22.92%	14.58%	14.58%	-	47.92%
Employees Awareness Trainings	39.58%	35.42%	8.33%	14.58%	2.08%
Internal Evaluation using KPIs	54.17%	2.08%	16.67%	16.67%	10.42%
Transportation	54.17%	16.67%	8.33%	6.25%	14.58%
Ingress and Egress	10.42%	56.25%	10.42%	18.75%	4.17%
Construction Stage					
Materials dispose off	12.5%	33.93%	21.43%	12.5%	19.64%
Renewable Energy use at site	53.57%	12.5%	5.36%	26.79%	1.79%
Dust Suppression Plan	64.29%	10.71%	25%	-	-
CO_2 emissions and Embodied Energy (EE)	87.5%	5.36%	7.14%	-	-
Air Quality: SO_2 and NO_x	55.36%	39.29%	5.36%	-	-
Air Quality: Ozone	7.14%	76.79%	14.29%	1.79%	-
Air Quality: Particulate	73.21%	19.64%	3.57%	3.57%	-
Obstruction of light by smoke	19.64%	17.86%	16.07%	21.43%	25%
Noise prevention plan	57.14%	35.71%	7.14%	-	-
Local Community services disruption	17.86%	17.86%	42.86%	10.71%	10.71%
Time lost through regulatory restrictions	21.43%	12.5%	25%	41.07%	-
De-Mobilization Stage					
Plant reuse	16.13%	35.48%	16.13%	32.26%	-
Equipment on de-mobilization	19.35%	25.81%	25.81%	19.35%	9.68%
Time Overruns	38.71%	25.81%	35.48%	-	-
Cost Overruns	32.26%	35.48%	29.03%	3.23%	-
Monitoring and Long-term Stage					
Powering monitoring stations	64.71%	17.65%	11.76%	5.88%	-
Contingency Planning	17.65%	20.59%	17.65%	41.18%	2.94%
Maintenance	47.06%	41.18%	11.76%	-	-
Client Satisfaction	11.76%	8.82%	29.41%	50%	-
Insurance & Warranties	20.59%	14.71%	52.94%	11.76%	-
Average	**35.76%**	**23.76%**	**20.75%**	**11.83%**	**7.89%**

3.3 Interpretations

From the results mentioned in Table 26, the following conclusions have been drafted:

1) 80.30% of the firms in Pakistan do not use any sustainability assessment tool at all. The rest reported using BREEAM, CEEQUEL, Eco-Points, LEED, Sigma, and SPeAR. None of the currently used assessment tools can be applied to the

field of geotechnical engineering. This is a clear indication that researchers are in a definite need of developing a sustainability assessment criterion /technique for geotechnical projects.

2) None of the firms is ISO 14001 certified even though 62.12% of the firms that participated in this survey are aged 20 and above, which reflects that Pakistan is far away from the SD goals.
3) Almost 50% of firms carry out monitoring activities. The majority of the firms carry out maintenance activities at regular intervals which highlights the poor quality-control measures during the construction. This is one of the reasons of minimal client satisfaction as the value for money is not attained as planned/expected.
4) A good percentage of the project cost is dedicated to site investigations (lab and field tests), which is appreciable because these investigations help reduce the uncertainties for design purposes and help strengthen the RMP and QRA, which ultimately help in controlling cost overruns.
5) The majority of the firms do not have an RMP and QRA which reflects why the projects face overruns in terms of both time and cost. The level of risk is unknown and therefore cannot be quantified.
6) H&S policies are not part of the majority of the projects the same as QRA and RMP.
7) LCA is not carried out by these firms, again one of the reasons for cost overruns. The reason for not doing this no monitoring and inexperience and the lack of a developed technique.
8) Firms continue with the least cost-competitive tenders which reflects no use of sustainable items along with poor construction practices, focusing on the economic aspects and ignoring other 3 Es.
9) As studied previously, the majority of the firms do not have any RMP or QRA or any H&S policy, and neither go for LCA, reflecting and confirming no awareness training. This is one of the reasons that evaluation using KPIs is not carried out.
10) Material wastage is very common, thereby compromising the economic and social aspects of sustainability.
11) More than half of the firms do not use any renewable energy systems. That is the reason that CO_2 and EE calculations are not carried out. Mostly allow VOCs to combine with air. This also shows the higher usage of coal/oil and very few firms using clean technology to maintain air quality.
12) Noise prevention plan not implemented compromises the social aspects of sustainability.

4 FRAMEWORK

4.1 *Framework of Geo-SAT*

The lack of a sustainability assessment tool urges the need for a new tool. Following detailed literature of assessment techniques and sustainability in general and specific to construction and geotechnics, Geo-SAT was developed using the four pillars of sustainability and the framework is shown in Figure 32. Each aspect is divided into stages which are assessed using indicators summarized in Figure 32. The number against each aspect and stage is the number of indicators developed. Each indicator is assessed on a scale of 1 to 5, similar to Table 25. The assessment for each stage is averaged and plotted on a graph as shown in Figure 33. The greater the area of the closed polygon, the more sustainable is the project. The complete details can be assessed at [13] and [14].
Geo-SAT ensures the embedment of SD targets into geotechnical projects. This required categorizing of main objectives to 5 sub-objectives as detailed below:

1) Understanding the prerequisites of sustainable design in the geotechnical field, 2) Understanding the 4 Es of sustainability and their impacts, 3) Defining the areas of least and the most impact on sustainability, 4) Defining improvements in the design process, 5) Correlating all the decisions on a project level to ensure sustainability at each stage

4.2 Framework of Assessment

These objectives can be achieved using the framework shown in Figure 34.

1) *Pre-Assessment:* All parties (engineers, clients, contractors, and suppliers) involved in the project must have clear communications to establish the concerns and understandings related to SD at this stage.
2) *Scope of Assessment:* Ensuring the scope of the assessment is necessary along with defining the boundaries of the site and project but flexibility of scope is mandatory. It also involves the identification of a realistic timeline.
3) *Data Collection*: The next step is to collect data for each indicator without compromising its quality.
4) *Baseline Assessment:* Carry out an initial assessment called the baseline assessment. This assessment will serve as a guideline for future references.
5) *Life Cycle Analysis*: Carry LCA at this stage. It is indeed an expensive and time-consuming process. Ideally, it should be done for all stages and indicators, but due to the complexities, there will always be limitations in extension. Another difficulty is the unexpected events that may come through the whole life of a project because LCA is based on creating assumptions and scenarios to come up with some outcomes.
6) *Identification of weak areas:* Identify areas where improvements are required in line with the resources and timeline.
7) *Re-assessment:* Carry out assessment at this stage incorporating the changes made to achieve improvements.
8) *Iterative assessment:* Keep on assessing the project with changes incorporated for continuous improvement.

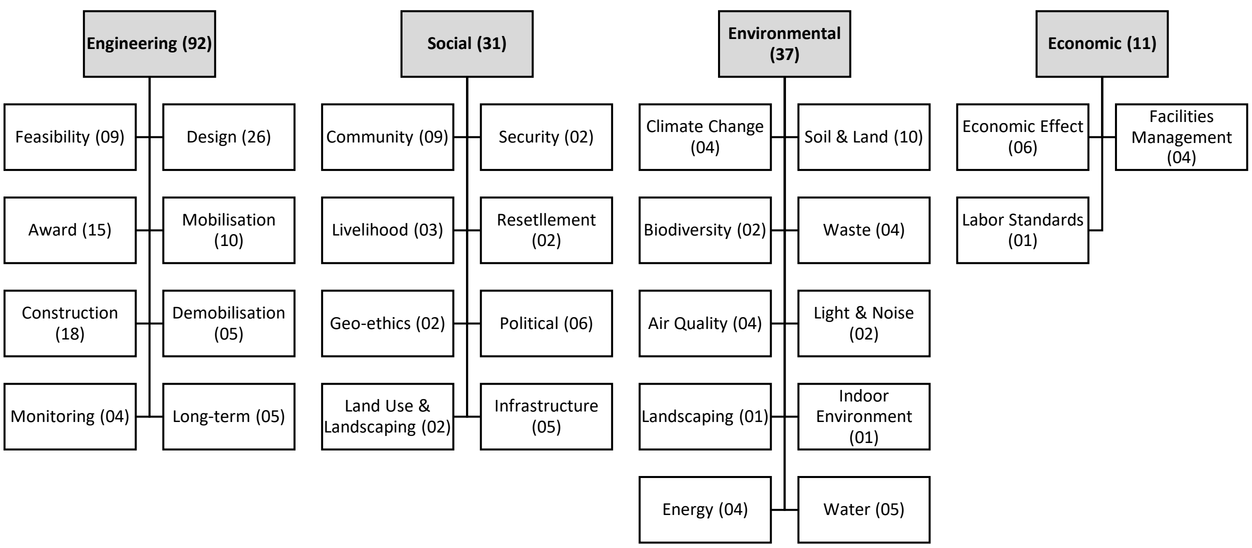


Figure 32: Framework of Geo-SAT

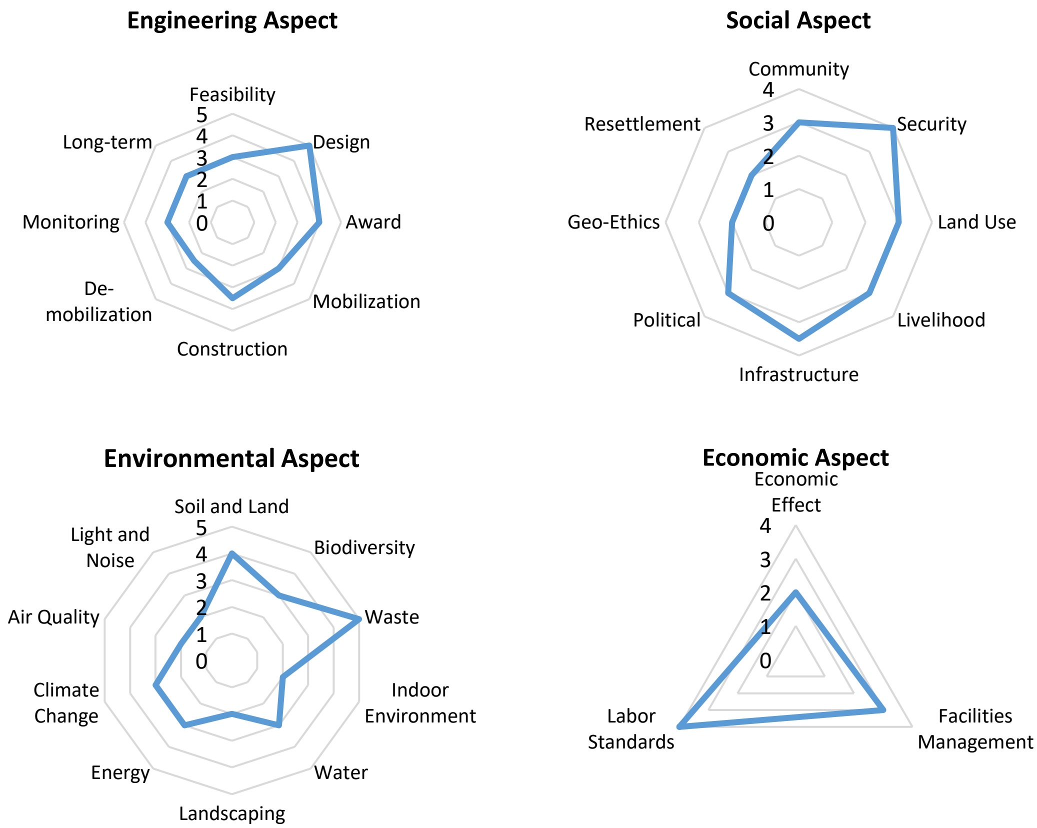


Figure 33: Sample Geo-SAT Averaged Points

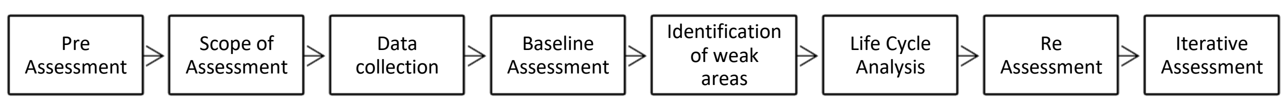


Figure 34: Framework for Geotechnical Assessment

5 CONCLUSION

Following conclusions can be drawn from the conducted study:

- The average is maximum for "detrimental" impact whereas minimum for "significantly improved" showing the poor performance of Pakistan's construction industry in terms of sustainability. The average would have been even low if it were not for types of tests and nuisance notices served. A majority of the firms have not received any formal nuisance notices, comparing with the other survey results, it is easily concluded that the local bodies have failed in terms of the social aspect of sustainability.
- Only a few of the firms have knowledge related to sustainability therefore, at the national level, it is required to incorporate this into the system through awareness lectures and seminars. Sustainability should be made part of the curriculum. The government also needs to take responsibility for arranging awareness through media.
- Community consultation plans should be developed at local and national levels and need to be followed as social aspects of sustainability are as important as the economic factors. The social aspect is majorly avoided and is one of the main reasons for being far behind the goal of achieving sustainability in the projects.

- Based on 171 indicators specific to geotechnics, Geo-SAT gives flexibility of exclusion as per the project's nature.
- The frameworks discussed will act as potential codes of sustainability in the field of geotechnical engineering.

ACKNOWLEDGMENT

The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] G. H. Brundtland, Report of the World Commission on environment and development:" our common future.". United Nations, 1987.
[2] R. Johnston, "Arsenic and the 2030 Agenda for Sustainable Development," *Arsenic R,* p. 12, 2016.
[3] M. K. Dixit, J. L. Fernández-Solís, S. Lavy, and C. H. Culp, "Identification of parameters for embodied energy measurement: A literature review," *Energy and buildings,* vol. 42, no. 8, pp. 1238-1247, 2010.
[4] R. Farooqui and S. Ahmed, "Assessment of Pakistani construction industry–current performance and the way forward," *Journal for the Advancement of Performance Information & Value,* vol. 1, no. 1, 2008.
[5] BRE, "BREEAM UK New Construction " BRE Global Limited, Watford, United Kingdom, Technical Manual SD5076, 11/02/2014 2014, vol. 1. [Online]. Available: https://files.bregroup.com/breeam/consultations/SD5078_DRAFT-UK_nondom_NC_2018-manual.pdf
[6] HOK, IMT, and DRES, "LEED Certification Guidebook," ed, 2008, p. 71.
[7] P. Watson, P. Mitchell, and D. Jones, "Environmental assessment for commercial buildings: Stakeholder requirements and tool characteristics," *https://digitalcollections. qut. edu. au/1661/,* 2004.
[8] ARUP. "Sustainable building designs strategy." https://www.arup.com/expertise/services/buildings/sustainable-buildings-design (accessed.
[9] ISI, "Envision rating system for sustainable infrastructure," ed: ISI and Zofnass Program for Sustainable Infrastructure Washington, DC, USA, 2015.
[10] A. Misra and D. Basu, "Sustainability in geotechnical engineering," *Internal Geotechnical Report,* vol. 2, 2011.
[11] D. Basu, A. Misra, and A. J. Puppala, "Sustainability and geotechnical engineering: perspectives and review," *Canadian Geotechnical Journal,* vol. 52, no. 1, pp. 96-113, 2014.
[12] I. Jefferson, D. V. Hunt, C. A. Birchall, and C. D. Rogers, "Sustainability indicators for environmental geotechnics," in *Proceedings-Institution of civil engineers engineering sustainability*, 2007, vol. 160, no. 2: INSTITUTION OF CIVIL ENGINEERS, p. 57.
[13] F. Raza, B. Alshameri, and S. M. Jamil, "Assessment of triple bottom line of sustainability for geotechnical projects," *Environment, Development and Sustainability*, 2020/05/29 2020, doi: 10.1007/s10668-020-00786-y.
[14] F. Raza, B. Alshameri, and S. M. Jamil, "Engineering aspect of sustainability assessment for geotechnical projects," *Environment, Development and Sustainability,* 2020/07/18 2020, doi: 10.1007/s10668-020-00876-x.

CHALLENGES IN ADOPTION OF BIG DATA IN CONSTRUCTION INDUSTRY OF PAKISTAN

[a] Sulaiman Javed, [b] Furqan Ali [c] Wajahat Ali Khan, [d] Hamza Nadeem, [e] Dr. Khurram Iqbal Ahmad Khan
a: Author. NUST Institute of Civil Engineering, National University of Sciences and Technology, Islamabad, Pakistan. Email: sulaiman.javaid987@gmail.com
b: Author. NUST Institute of Civil Engineering, National University of Sciences and Technology, Islamabad, Pakistan. Email: faroki@live.com
c: Author. NUST Institute of Civil Engineering, National University of Sciences and Technology, Islamabad, Pakistan. Email: wajahatkhattak97@yahoo.com
d: Author. NUST Institute of Civil Engineering, National University of Sciences and Technology, Islamabad, Pakistan. Email: hamza.jutt689@gmail.com
e: Corresponding Author. NUST Institute of Civil Engineering, National University of Sciences and Technology, Islamabad, Pakistan. Email: dr.khurram.iqbal.khan@gmail.com

***Abstract*:-**Construction industry has an important part to play in the development of a country. There has been a recent growth in this sector after government incentivizing the industry; however, due to the prevalent traditional practices projects often exceed the constraints. With increasing infrastructure development, there has been felt a need to employ Big Data management in the construction sector to manage the huge chunks of data being produced annually. Big Data, being a rising concern, is driving huge IT investments to manage and maintain it in different sectors like genomics, simulations, environmental research, urban informatics, business and e-science etc. A research was carried out to identify the basic challenges that pose in way of formulation of a Central Big Data Management System in Pakistan for construction sector, under government supervision. The challenges were identified through a frequency analysis of the respondents, which included clients, consultants and contractors. The study highlights the importance of a central management system to increase productivity and efficiency, lower costs and risk involved and optimize the construction practices.

Keywords- Big Data in construction industry, Big Data in Pakistan, Big Data Management System, Hadoop.

1 INTRODUCTION

Once considered an archaic industry, the construction world is going through a rapid shift. Numerous people and organizations are trying their best to make this one of the modern industries. Construction industry carries out the most expensive and huge projects and generates large amount and variety of information [1]. This data and information come from people, documents, computers, machines, or any other data-generating devices or agents [2]. However, due to lack of proper storage and analytics of the information, the construction sector is not using the past data.

This information will lead towards the decrease in the risks and costs, and increase in productivity and efficiency as Big Data helps organizations to get around 5-6% more profit [3]. Furthermore, activity duration and work schedule can be determined when project is in conceptual stage with the help of algorithm analysis of the data [4]. But this data is not being utilized in the best of its ways because construction industry of Pakistan lacks probing of ways to manage the data and research on central Big Data management system where data can be stored and retrieved easily.

1.1 Big Data

Big Data is the term used for the representing immense amount of data sets containing huge, much diverse, having both structured and unstructured data that is so huge and problematic to process by using customary techniques and software methods, and have problems of storage, analyzing, evaluating and envisioning for more processes or results [5]. The most prominent attributes of Big Data are referred as 3 Vs i.e. Volume (Amount of Data), Variety (Type or format of Data) and Velocity (Speed or Rate of Data Processing or Generation) [6].

1.2 Big Data Implementation

Big data is useless in the vacuum. Its importance is revealed while making decisions. To allow such evidence and research-based processes for making decisions, organizations need effective methods and processes to make great volumes of very fast moving variety of data into significant results [7]. The overall process for the extraction of results and insights from big data can be divided into five stages i.e. acquisition, extraction, integration, analysis and interpretation [8].

The most commonly used method for Big Data is the Hadoop, which is based on Google's Map Reduce method and Google File System. Hadoop is a distributed batch-processing infrastructure, which consists of the Hadoop kernel, Hadoop Distributed File System (HDFS), Map Reduce and several related projects [9]. It is a block-structured distributed file system, which is aimed to hold massive amounts of data, in a consistent, reliable, accessible and an easy way to function and operate with avoiding failure [10].

2 RESEARCH METHODOLOGY

Our research work comprised of qualitative literature review and questionnaire survey.

2.1 Qualitative Literature Review

Qualitative Literature Review was necessary to draw insights on the vast and wider research avenue of Big Data. This review was entirely aimed to map out the potential factors that are influencing the implementation of Big Data in construction industry. A thorough study of research papers highlighted twenty-eight factors. All the factors were assigned frequency and ranking (Low, Medium, High according to its emphasis in research paper) and were later shortlisted based on their normalized score obtained through computations on Microsoft Excel as shown in Table 1:

Table 1: Content Analysis

Factors Affecting Adoption of Big Data	Literature Score	Rank	Factors Affecting Adoption of Big Data	Literature Score	Rank
Data Management	0.4	1st	Acquisition of Data	0.1	8th
Data Volume	0.36	2nd	Complexity of Data	0.1	8th
Data Storage	0.35	3rd	Adopter's Readiness	0.1	8th
Data Quality	0.35	3rd	Legal Issues	0.09	9th
Data Analysis	0.35	3rd	Lack of Technology	0.09	9th
Type of Data	0.27	4th	Lack of Senior Management's Interest	0.09	9th
Security of Data	0.2	5th	Innovation	0.09	9th
Data Collection Capacity	0.2	5th	Hadoop Expertise	0.06	10th
Lack of IT expertise	0.2	5th	Policy Making	0.06	10th
Organizational Capability	0.15	6th	Pressure from Business Partners	0.05	11th
Regulatory Support (Govt. Support)	0.15	6th	Attitude towards technology adoption	0.05	11th
Data Sharing	0.15	6th	Trust and Cooperation	0.04	12th
Confidentiality	0.15	6th	Competitive Advantage	0.03	13th
Data Velocity	0.12	7th	Client Requirement	0.01	14th

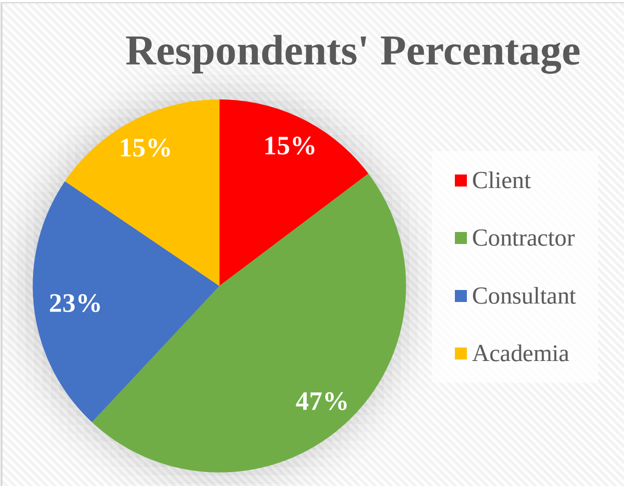
2.2 Survey

In order to validate the potency of factors extracted from qualitative literature review, a web-based questionnaire was developed using Google Forms. The questionnaire consisted of three portions; first section was about respondent's profile, second section was about awareness of Big Data leading to a third section that consisted of a list of factors on Likert scale of 1 (Very Low) to 5 (Very High).

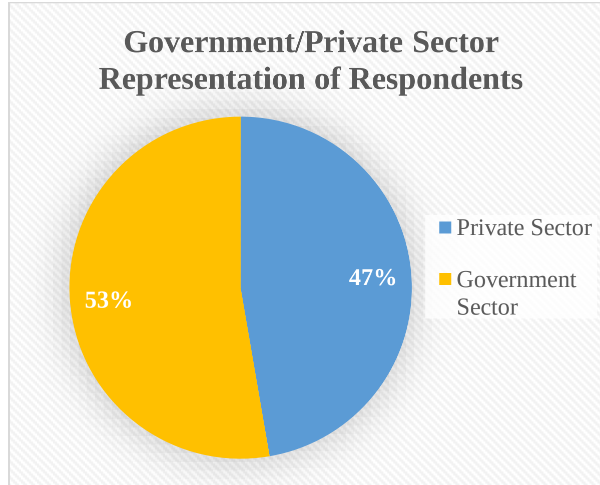
The questionnaire was shared via emails and was circulated through personal contacts among concerned academia and industry personnel with experience and knowledge of Big Data in construction Industry. A total of 129 responses were received from the survey conducted.

2.3 Respondents' Profile

It has been observed that majority of our respondents were contractors (47%) followed by consultants (23%), client (15%) and academia (15%). Figures 1 shows respondents' percentage depending upon their professional background. Whereas, Figure 2 gives the percentage of government and public sector representation of the participating respondents.



a



b

Figure: a, b Respondent's Data

3 RESULTS

Responses obtained from the survey form were analyzed through frequency analysis in a statistical software "IBM SPSS Statistics 20" to rank the factors that are major roadblocks in the way of adoption of Big Data. It comes out that Security of Data, Data Acquisition and Policy Making are the forefront issues in establishing a Central Big Data Management System. Figure 2 shows the spectrum of factors along with their average value on Likert scale.

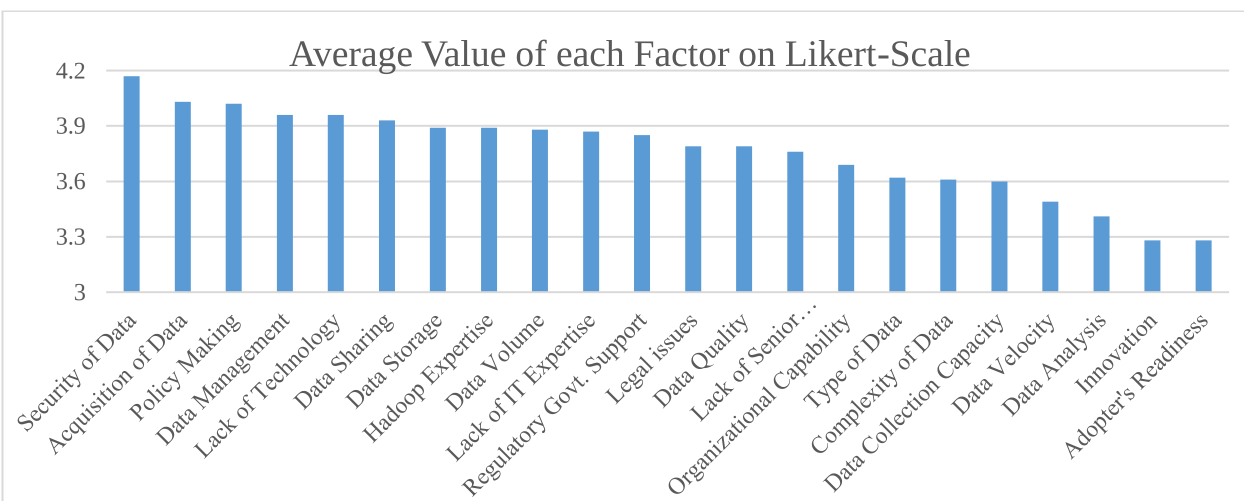


Figure 3: Factors on Likert-Scale

4 FRAMEWORK

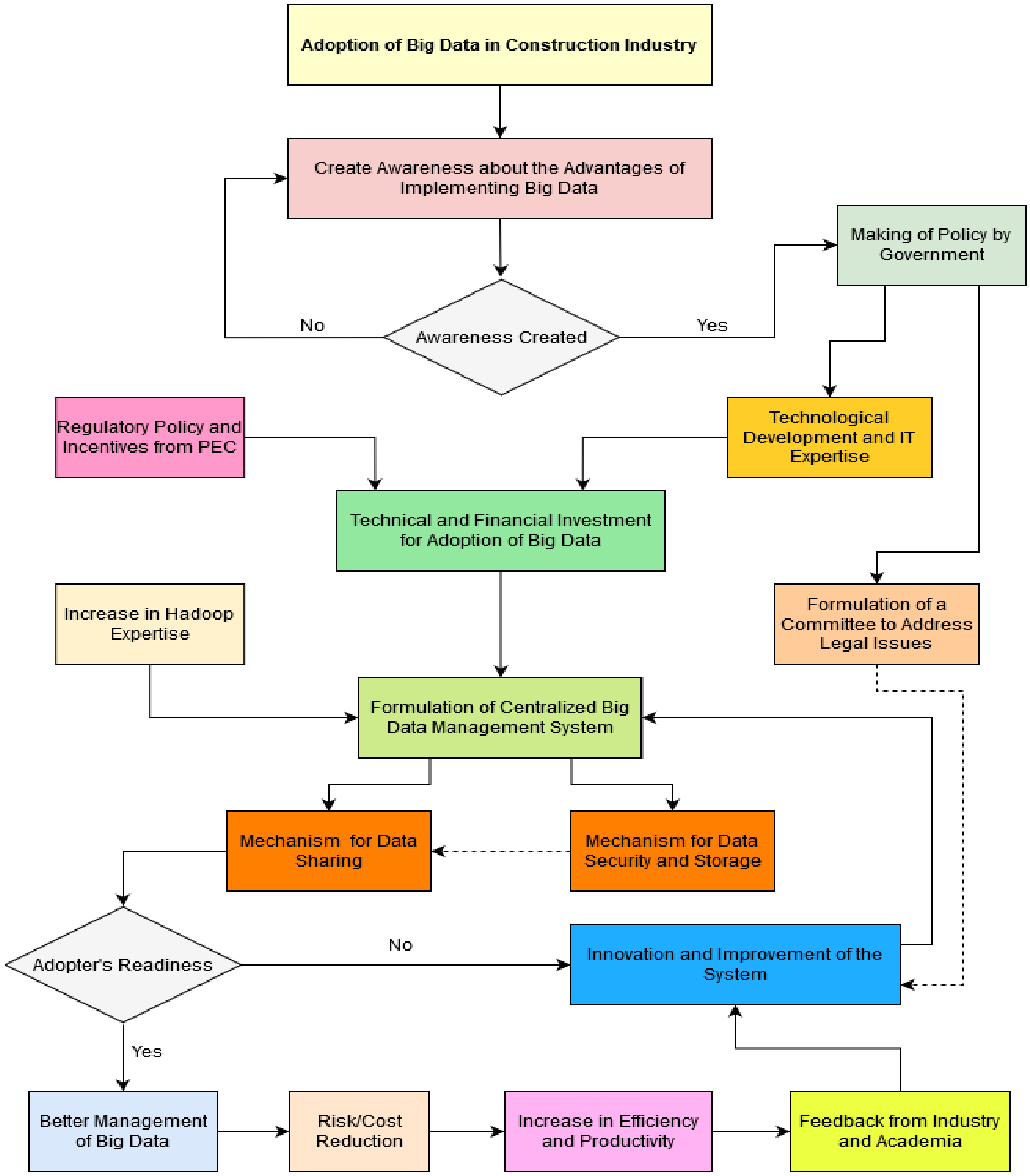


Figure 4: Conceptual Framework for Adoption of Big Data

After identification of the factors, a conceptual framework has been devised to map out a way forward for the adoption of Big Data in the construction industry of Pakistan. It comprised of, and not limited to the following major steps:

- The framework begins with the substantial awareness about the advantages of Big Data for the construction firms, which are working under Pakistan Engineering Council (PEC).
- Proper policy should be formed in this regard with the help of ministerial level support to formulate a Centralized Big Data Management System (BDMS) to store and share data. It will lessen the roadblocks as well as converge people towards relying on better technologically advanced methods for construction practices in Pakistan and applying them in order to achieve results that are more beneficial.
- Increase of Hadoop expertise in the country, which is a software utility to manage Big Data.

- Formation of a committee to address the legal issues that possibly may arise during the process.
- Seek adopter's readiness to improve the BDMS based on the feedback.

Once applied in its entirety, this system shall ensure a competitive advantage for the exercising firms and help in increasing efficiency and productivity in construction practices. Efficient Big Data management shall also reduce cost involved in major projects carried out in Pakistan.

5 CONCLUSIONS

This research paper primarily focusses on identifying hindrances in the adoption of Big Data in construction industry. Qualitative literature review was conducted and because of that, we obtained literature score and challenging factors were shortlisted. It was followed by Frequency Analysis of the responses received from survey, which helped ranking the challenges that inhibit the leveraging of Big Data among practitioners. A conceptual framework was proposed highlighting that a proper management system shall be made under government support that can ensure the collection, secure storage, and retrieval of data maintaining the competitive advantage of the contributing firms. This will largely require technological development and financial investment. Government should lower the legal barriers as well as take measures to make the senior management in the construction firms' adaptive to the new technology.

The project scope encompassed a general roadmap towards the adoption of Big Data in the local industry whereas future research should endorse the validity of proposed framework by translating it into practice and amending new possibilities that may arise with time.

6 LIMITATIONS

The research on Big Data adoption had several limitations, first one being the lockdown situation during the outbreak of pandemic COVID-19, due to which we had to limit our scope and physical outreach to the stakeholders. Secondly, a large number of people in Pakistan are not even aware of the term Big Data, and hence could not participate in the survey.

ACKNOWLEDGMENT

We would like to thank every person who helped thorough out the research work, particularly CE&M department and specially Dr. Khurram Iqbal Ahmad Khan. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] L. Yun, Y. Manzhu, X. Mengchao, et al., "Big Data and Cloud Computing," *Manual of Digital Earth*, pp. 325-355, 2019.

[2] Z.N. Maaz, S. Bandi and R. Amirudin, "A Contextual Parsing Of Big Data Values To Quantity Surveyors," *International Journal Of Built Environment And Sustainability,* vol. 5, no. 3, pp. 241-50, 2018.

[3] P. kaur and J. Malhotra, "A Review of Trends and Opportunities for Data Mining Application in Telecommunications Industry," *International Conference on Communication, Computing & Systems (Icccs*), pp. 128-133, 2014.

[4] A. McAfee and E. Brynjolfsson, "Big Data: The Management Revolution," *Harvard business review,* vol. 90. pp. 60-6, 2012.

[5] M. Bilal, L. Oyedele, J. Qadir, et al., "Big Data in the construction industry: A review of present status, opportunities, and future trends," *Advanced Engineering Informatics*, vol. 30, pp. 500-521, 2016.

[6] S. Sagiroglu, and D. Sinanc, "Big Data: A Review, Collaboration Technologies and Systems (CTS)," *International Conference on Digital Object Identifier*, pp. 42-47, 2013.

[7] B. S. P. Mishra, S. Dehuri, E. Kim, et al., "Techniques and Environments for Big Data Analysis," *Studies in Big Data,* vol. 17, 2016.

[8] A. Labrinidis and H..V. Jagadish, "Challenges and Opportunities with Big Data," *Proceedings of the VLDB Endowment*, vol.5 no.12, pp.2032-2033, 2012.

[9] M. Shorfuzzaman, "Leveraging Cloud Based Big Data Analytics in Knowledge Management for Enhanced Decision Making in Organizations," *International Journal of Distributed and Parallel Systems (IJDPS)*, vol.8, no.1, pp.1-13, 2017.

[10] D. Garlasu, et al., "A Big Data implementation based on Grid Computing," *11th Roedunet International Conference*, 2013.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

SUSTAINABLE CONSTRUCTION RISK ASSESSMENT THROUGH DYNAMIC SITE LAYOUT PLANNING AND SIMULATION BY BUILDING INFORMATION MODELLING

[a] Alina Mahmood, [b] Khuram Rashid, [c] Abdul Wadood
a: Department of Architectural Engineering and Design, University of Engineering and Technology, Main GT Road-54890, Lahore, Pakistan, alinakhan@live.com
b: Department of Architectural Engineering and Design, University of Engineering and Technology, Main GT Road-54890, Lahore, Pakistan, khuram_ae@uet.edu.pk
c: Department of Architectural Engineering and Design, University of Engineering and Technology, Main GT Road-54890, Lahore, Pakistan, Unisons International Pvt. Ltd., awadood138@gmail.com

Abstract- Construction industry is prone to risks due to the dynamic nature of activities and the placement of numerous facilities at site. Mostly, site layouts are treated as static, whereas, construction projects are dynamic in nature, whose requirements change over time. With the growing concern for sustainable development in construction sector, it is imperative that risks at construction projects related to all aspects of sustainability; social, economic and environmental must be evaluated. Therefore, dynamic site layout planning integrating sustainability risks was performed in this study. A model considering the interaction flows between construction facilities and their safety/environmental concerns was employed to assess the safety risks for the sustainable site layout planning. A case study of a commercial building project of developing country was selected to validate the safety risk assessment model. The interaction flows between facilities and their safety/environmental concerns were evaluated and risk of site layout was calculated for the case study. The risk assessment model was then optimized by varying the interaction flows for all phases of project and a new site layout scenario was developed with reduced risks. Sustainability risks arising due to various facilities were evaluated from their interaction flows and safety/environmental concerns. Building Information Modeling (BIM) was used to develop the dynamic site layout scenarios. By dynamic site layout planning risky nature of construction site was reduced by 26.47% and social, economic and environmental risks are reduced by 25.43%, 18.31% and 17.71% respectively. This model is valid for a variety of construction and infrastructure development projects and can be used by various stakeholders of the construction industry for sustainable site layout planning.

Keywords- Building Information Modeling, Construction Safety, Construction Site Layout Planning, Sustainability Risks Assessment

1 INTRODUCTION

Construction site layout planning is one of the most overlooked aspects at construction projects and is subject to the decision of the project manager [1]. The facilities are usually allocated at the site on first come basis without giving any consideration to the associated hazards and risks. Failure to plan the site layout creates conflicts at site which leads to operational inefficiency, increasing the safety risks and the overall cost of a project substantially [2]. In construction projects, site space is a precious asset that should be meticulously and productively designed. Construction site layout planning requires identifying site facilities, defining their size and allocating location for these facilities on site [3]. The temporary facilities include heavy equipment and machinery, material and components storage areas, operation plants, site accessories and residence areas [4]. As the project progresses, more number of facilities are added in the site increasing the complexity of layout and thus more constraints to look for. In addition, as construction evolves, the site layout may need to be dynamically reorganized at various schedule intervals to accommodate the operational needs. The complexity of site layout planning can be dealt with Building Information Modeling (BIM) tools [5, 6]. BIM has been perceived as an advance tool which has revolutionized the construction industry. BIM can be used to provide users with a safe site layout plan by its dynamic planning and 4D simulation features. This is vital to ensure the safety of the working environment and for efficient operations. BIM is a tool that represents physical characteristics as well as functional abilities of a facility. BIM model is data rich, item oriented, intellectual and parametric illustration of facility after that views as well as data fitting to numerous users' desires can be gained and then analysis can be done to produce evidence that are used to mark results and increase workability. The utilization of BIM for facilities layout planning is a relatively new practice of BIM.

Many of the project delays, cost overruns and fatalities are due to the improper site layout planning. These risks are social, economic and environmental in nature. Social risks are related to labor disputes and strikes, labor productivity and defective work, theft and vandalism, epidemic illness and accidents affecting the health and well-being of construction workers. Economic risks are due to the increased transportation costs of materials within site, warehouse fee, set-up and dismantling cost of facilities, price inflation of construction materials, incomplete or imprecise cost estimate, etc. Environmental risks are concerned with pollution as a result of construction activities (level of noise, dust, excessive vibrations, potential energy, and site wastes), adverse weather conditions, and force majeure [7-9]. A safety risk assessment was performed by Ning et al. [10] on a construction project with 16 facilities in total. The site layout was planned and 3 scenarios were developed. The safety risks were calculated for the temporary facilities and all the locations that are still unoccupied within the site boundary. The total safety risk level of site layout for the scenario 2 (80.99) was found to be the least as compared to scenario 1 and scenario 3. This shows that construction projects with various facilities have a huge untapped potential to reduce the safety risks by proper planning of the site layout. This can also have huge implications for reducing the social, economic and environmental risks related to site. Site layout planning is not limited to construction sites only, it can be applied to manufacturing and production facilities as well. Dynamic layout planning was implemented on case study of steel fabrication industry and benefit in terms of reduction in haulage time was observed [11].

The aim of this work is to formulate a dynamic site layout plan, in order to minimize safety and sustainability risks. This is achieved by devising a safe construction site layout plan by quantifying the risks associated with construction facilities. The work identifies the temporary facilities required at each project phase, determining facilities' required characteristics (size, shape, orientation, etc.). The project is divided into phases and site layout planning is treated as a dynamic activity. The solution is developed considering the placement of facilities at various locations by manipulating their distance, interaction flows and safety/environmental concerns. This is done by taking into account the changes in construction schedule to avoid any relocation during project timeline. The work is validated through a case study project with an existing site layout and a modified site layout with reduced risks. Then, sustainability risks are calculated by manipulating the distance between facilities that can pose social, economic and environmental risks.

2 RESEARCH METHODOLOGY

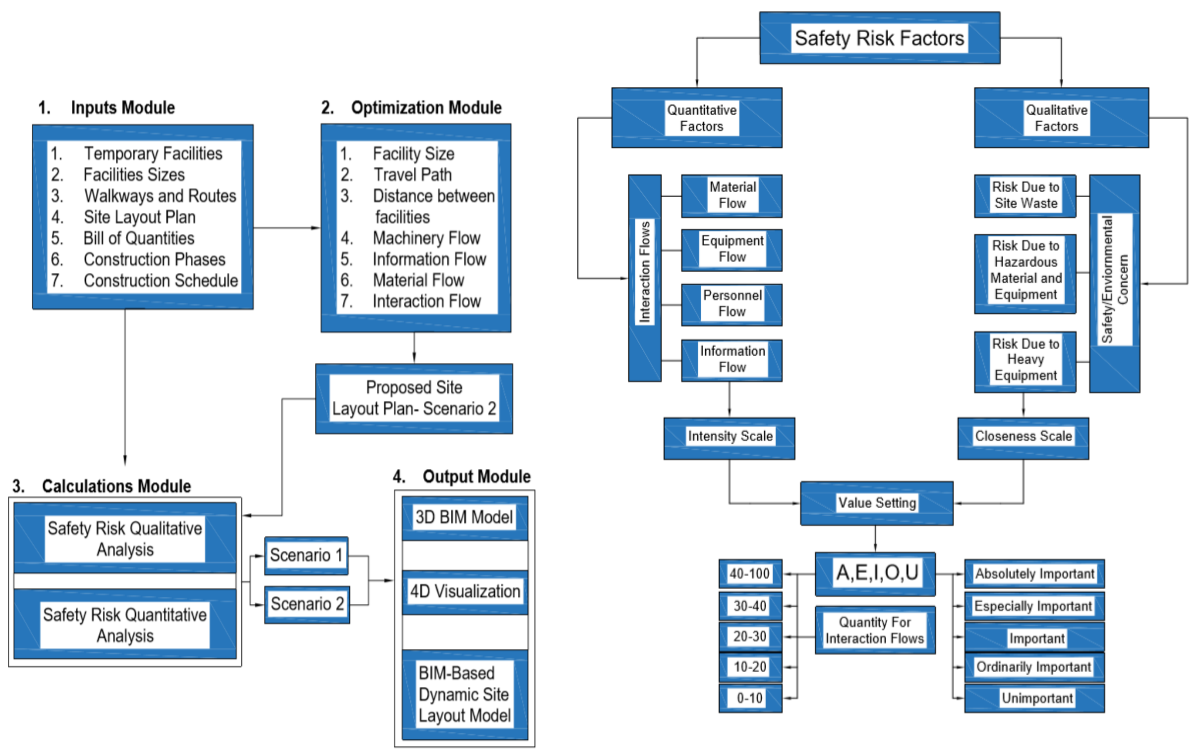
In the process of assessment of safety risk factors, the relevant literature was reviewed and the temporary facilities at construction sites were reviewed. As an input the interaction flows and safety/environmental factors were assessed for each facility. Site layout scenarios were developed before and after the risk assessment process. The working methodology of this work is given in Figure 1 (a).

2.1 Construction safety risk factors analysis scale.

The safety risk factors are either taken as quantitative or qualitative as defined by Ning et al. [10]. The quantitative risk factors are the interaction flows between facilities, as there is a constant flow of materials, labour, equipment and information between the facilities. The risks which arise due to; waste at site (excessive noise, dust, vibrations, energy, temperature); hazardous materials (explosives, chemicals, inflammable materials, fuel, high voltage) and any hazardous equipment; and the risks due to the presence of heavy equipment (tower crane, material hoists) are taken as qualitative risks. An intensity scale consisting of five ranks is used to measure the quantitative risk factors. A closeness scale of five ranks: A (absolutely important), E (especially important), I (important), O (ordinarily important) and U (unimportant) which is decided by the project manager at site is used to measure the qualitative risks and is defined in Figure 1 (b). A construction site consists of occupied locations by temporary facilities, unoccupied locations and any buildings which are already existing at site. The total safety risk level of the construction site should consider the occupied locations by temporary facilities and unoccupied locations for future placement of facilities. Dangerous facilities such as tower crane, material hoist and workshops around unoccupied locations pose a risk to them. The location of temporary facilities is greatly influenced by the presence of dangerous facilities around them and the intensity of various flows termed as interaction flows between these facilities. So, the total safety risk level of the site layout plan is calculated in terms of the interaction flows due to material, equipment, personnel and information; and the various safety/environmental concerns. Assessment functions are used to calculate the total safety risk level of the site layout plan.

2.2 Safety risk level considering interaction flows and safety/environmental concerns.

If the materials are frequently transported between facilities, and there is a frequent movement of equipment and labor (personnel) between the facilities with scarce communication; it results in an increased probability of accidents. Also, longer distances between facilities resulting in longer travel routes create more intersection points that lead to increased number of accidents. Distances between the temporary facilities affect the safety risk level so these distances are measured between each concerned facility as Euclidean distance. Risks that arise due to any site waste (noise, pollution, etc.), hazardous materials-and-equipment and heavy equipment affect the workers' health and safety on construction site. The falling objects from heavy equipment such as tower crane and material hoist represent potential hazards. So, there should be specific location for these equipment to minimize the construction site risk. Quantitative and qualitative risks are calculated for each facility in each phase and their summation gives the total safety risks of construction site layout. The social, economic and environmental risks are also evaluated by the relevant interaction flows and safety/environmental concerns of the facilities in each phase for scenario 1 and 2. The facilities interaction flows are manipulated to reduce the safety concerns due to the presence of dangerous facilities. The equations used to calculate the risks due to interaction flows and risks due to safety/environmental concerns are utilized from the work of Ning et al. [10].



a) b)

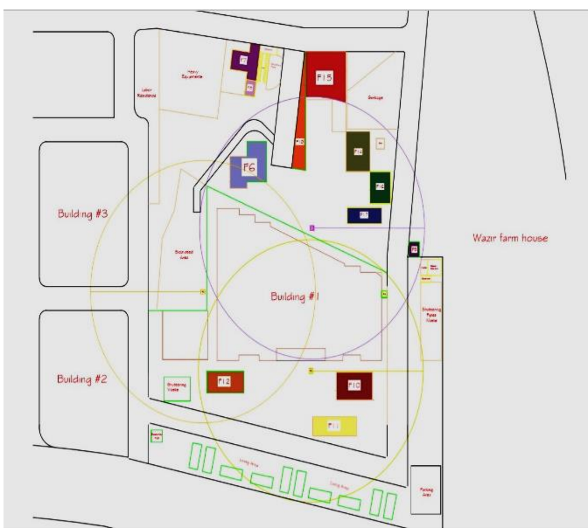
Figure 35 a) Working methodology b) Safety risk factors scale

3 CASE STUDY.

A case study of a live project is selected to verify the risk assessment method that enables the site managers to assess diverse site design situations and pick the best one with least safety risk level. Two different site layout scenarios are taken of a 14 story (2 basements, ground plus eleven typical floors) mixed-use building located in Lahore, Pakistan. The DCSLP is done for this case study by dividing the project duration into four phases on the basis of material requirements, equipment usage and changes in facilities arrangement at site. Then two site layouts (scenario 1 as shown in Figure 2 (a) and scenario 2 as shown in Figure 2 (b)) are developed and the site layout for the last phase (phase 4) is shown in Figure 2. First scenario is the existing site layout of the project (as decided by the project manager) and second scenario is the proposed site layout for the same site. In existing site layout, transportation routes and walkways are not defined between temporary facilities. Distances between temporary facilities are longer due to which the probability of collision and collapse increases that results in severe accidents and fatalities. The interaction flows between facilities are also greater that increases the likelihood of hazards. In proposed site layout proper routes and walkways are defined with safety zones. Distances and interaction flows between facilities are decreased that reduces the safety risk level and enhance the safety level. Also, the quantity of tower cranes has been reduced to 2 (as shown in Figure 2 (b)) instead of 3 (as shown in Figure 2 (a)) that will minimize the cost for heavy equipment and will also reduce the hazard of falling objects. The dynamic modelling of both site layout scenarios is done in Revit as shown in Figure 3 and the simulation is performed in Navisworks. The facilities involved in the various phases of the project and used to plan the site layout are listed in Table 1.

Table 27 List of temporary facilities at case study project

Facility	**Code**	**Size (m^2)**	**Facility**	**Code**	**Size (m^2)**	**Facility**	**Code**	**Size (m^2)**
Tower Crane # 1	F1	4	Rebar Bending Workshop	F7	120	Brick Yard	F13	112
Tower Crane # 2	F2	4	Testing Lab	F8	28	Gravel Yard (Sand)	F14	160
Tower Crane # 3	F3	4	Fuel Storage Area	F9	27	Gravel Yard (Crush)	F15	400
Material Hoist # 1	F4	7	Formwork Area-1	F10	410	Cement Yard	F16	110
Material Hoist # 2	F5	7	Formwork Area-2	F11	222	Batching Plant	F17	95
Steel Yard	F6	225	Shuttering pipes	F12	270	Steel Raw Material	F18	150

a) 

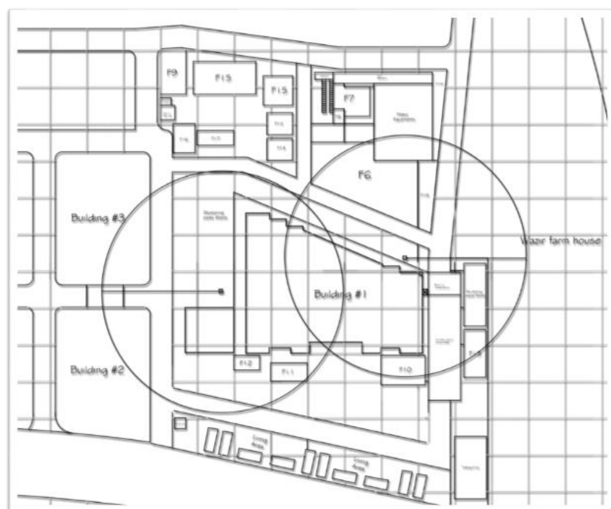
b) 

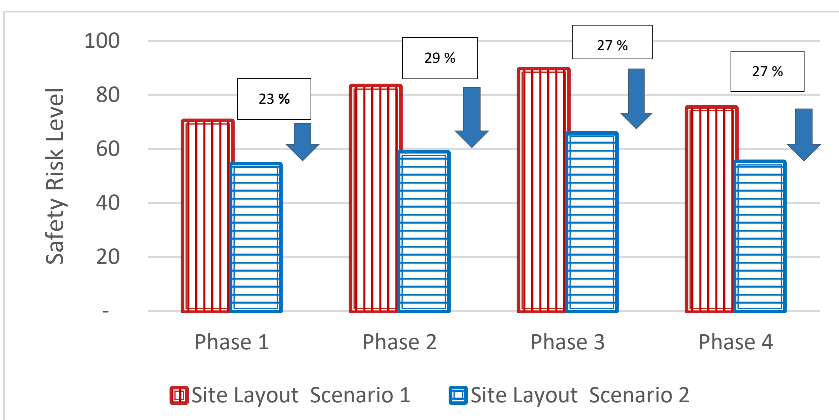
Figure 36 Construction site layout of phase 4 for a) Scenario 1 b) Scenario 2

4 RESULTS

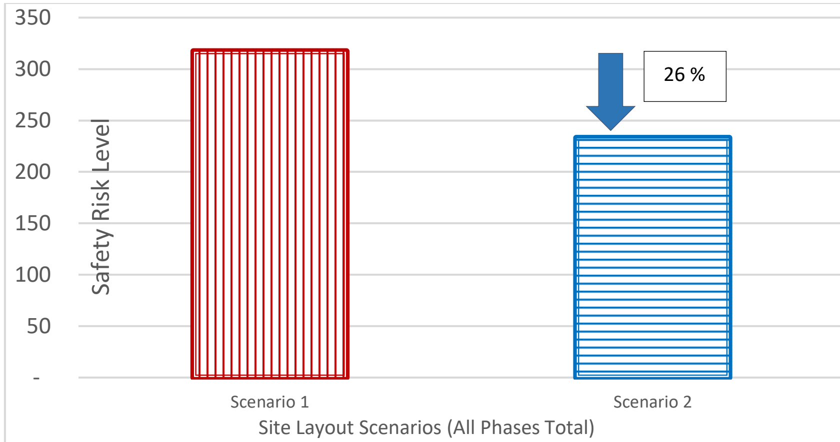
4.1 Risk assessment.

The safety risk level due to the presence of all the temporary facilities, unoccupied locations and site for four construction phases based on interaction flows and safety/environmental concerns is performed. A comparison of safety risk level is presented in Figure 4 (a) for each of the four phases of the project. The safety risk level has reduced from 23% for phase 1 to a maximum reduction of 29% for phase 2 in case of scenario 2. The maximum reduction in safety layout of 29% in phase 2 of the project is due to the presence of maximum number of facilities in that phase which provided an opportunity to the projected manager to effectively plan the facilities layout and thus reduce the many risks in that phase. The total safety risk level of site layout for the whole project (complete project lifecycle) in the site layout scenario 2 has lower value (233.09) than scenario 1 (317.34) due to proper planning of facilities location and position and effective utilization of unoccupied locations from previous phase in the next phase of the project, as shown in Figure 4 (b). The value of safety risk level of temporary facilities at construction site due to the various flows between facilities and safety/environmental concerns are 172.70 and 60.39 respectively for total four construction phases of scenario 2 which is lower than that of scenario 1 as 230.9 and 86.44 respectively. A maximum reduction of 25% is observed in the social parameter of sustainability risks. This is due to the fact that separate paths of vehicles are designed to reduce accidents due to collision, marking of safety zones (personal protective equipment-PPE zones and partial PPE zones) throughout the construction site and increasing the distance between dangerous facilities. It is observed that the sustainability risks values are lower for scenario 2 as compared to scenario 1 as shown in Figure 4 (c). Scenario 2 (after site layout planning) has the greater safety level than scenario 1 (before the site layout planning). Therefore, scenario 2 is the preferred site layout for the stakeholders of the construction project and the decision-makers on site.

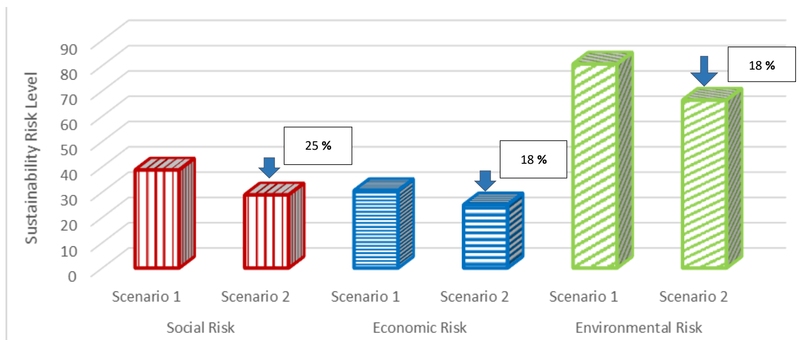
Figure 37 BIM model of construction site layout Scenario 2



a)



b)



c)

Figure 38 Safety and Sustainability risk level of site layout scenarios (a) safety risk level of phases, (b) total safety risk level and (c) social, economic and environmental risk level

4.2 Site layout modelling and simulation

BIM solutions include many attributes which offer several interesting opportunities to promote safety at construction sites. The visualization offers a totally new tool for risk assessment, planning, introduction, safety management etc. Additionally, 4D-BIM means improved chances to make alternative preliminary plans of different construction stages and tasks. In order to make the dynamic site layout, 3D model was created in Autodesk Revit for both scenarios. The structural model is on Level of detail (LOD) 300. A number of parametric and non-parametric components library was developed to achieve the desired LOD. Firstly, the information about project tasks was imported from schedule from the project planning software application. Then, linked elements in the composite model with tasks in the schedule. Finally, the schedule was simulated for all phases of project through timeliner of Navisworks.

5 APPLICATION IN FIELD

The construction industry is subjected to risks of varied nature on account of the presence of various hazards on site. These hazards are due to the use of equipment, machinery, vehicles and other facilities at site. These facilities if not properly planned and managed during the life of the project can lead to incidents and accidents that can incur huge financial and health related losses. Through dynamic site layout planning, the project managers can effectively and efficiently plan and manage various facilities at site. The site can be managed at each project phase to accommodate new and upcoming facilities without affecting the productivity of operations. The risks associated with facilities location, position and logistics can be identified beforehand and effective measures can be put in place to reduce these risks. The risks related to social, economic and environment can be evaluated for further mitigation. Planning the site layout of construction projects thus, has huge benefits for all the stakeholders of the construction industry to reduce additional site layout costs, improve productivity of labor and operations by reducing hazards and risks.

6 CONCLUSION

This paper reveals the importance of dynamic site layout planning to reduce safety and sustainability risks during the construction phases of project. The risk assessment integrating the various interaction flows and safety/environmental concerns of temporary facilities can be performed to evaluate safety and sustainability risks. This can help the project managers to evaluate construction site layouts and select the layout with minimum risk level. The working in this paper can be utilized to systematically and scientifically evaluate the safety and sustainability risks at each construction phase to come up with a site layout that has total minimum risks. Proposed layout (Scenario 2) is the optimized solution to safety issues as the safety risk level is reduced by about 26.47% as compared with scenario 1. This paper contributes in identifying and classifying risks related to construction site facilities. Sustainable construction site risks are also reduced by optimization of site layout including social risk (25.43%), economic risk (18.31%) and environmental risk (17.71%).The results obtained suggest that to reduce the safety risk level of construction site, the project managers are inclined to decrease the frequency of movement of materials, equipment and personnel between facilities; and minimize the distance between facilities. Temporary facilities which have greater flow of material, equipment and personnel between them should be placed close to each other to avoid any conflicts in operations. Dangerous facilities and heavy equipment should be located at far off distances from the temporary facilities specially residence facilities as the hazard decreases with distance. Also, special safety zones (personal protective equipment-PPE zones) should be developed around heavy equipment to reduce risks due to falling objects. Taking this study further, the future research can emphasize on the automated ruled based checking using BIM technology integrated with virtual reality for better and safe site layout planning and real time visualization of safety hazards.

ACKNOWLEDGMENT

The authors would like to thank Mr. Muhammad Aftab, Resident Engineer, case study project, who has been of great help in collecting data of the site. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] I. N. Papadaki and A. P. Chassiakos, "Multi-objective Construction Site Layout Planning Using Genetic Algorithms," Procedia Engineering, vol. 164, pp. 20-27, 2016/01/01/ 2016.

[2] K. Li, H. Luo, and M. J. Skibniewski, "A non-centralized adaptive method for dynamic planning of construction components storage areas," *Advanced Engineering Informatics,* vol. 39, pp. 80-94, 2019/01/01/ 2019.

[3] I. Abotaleb, K. Nassar, and O. Hosny, "Layout optimization of construction site facilities with dynamic freeform geometric representations," *Automation in Construction,* vol. 66, pp. 15-28, 2016/06/01/ 2016.

[4] X. Song, J. Xu, C. Shen, and F. Peña-Mora, "Conflict resolution-motivated strategy towards integrated construction site layout and material logistics planning: A bi-stakeholder perspective," *Automation in Construction,* vol. 87, pp. 138-157, 2018/03/01/ 2018.

[5] R. Bortolini, C. T. Formoso, and D. D. Viana, "Site logistics planning and control for engineer-to-order prefabricated building systems using BIM 4D modeling," *Automation in Construction,* vol. 98, pp. 248-264, 2019/02/01/ 2019.

[6] S. S. Kumar and J. C. P. Cheng, "A BIM-based automated site layout planning framework for congested construction sites," *Automation in Construction,* vol. 59, pp. 24-37, 2015/11/01/ 2015.

[7] X. Ning, J. Qi, C. Wu, and W. Wang, "Reducing noise pollution by planning construction site layout via a multi-objective optimization model," *Journal of Cleaner Production,* vol. 222, pp. 218-230, 2019.

[8] J. Hong, T. Hong, H. Kang, and M. Lee, "A Framework for Reducing Dust Emissions and Energy Consumption on Construction Sites," *Energy Procedia,* vol. 158, pp. 5092-5096, 2019/02/01/ 2019.

[9] M. Andayesh and F. Sadeghpour, "Dynamic site layout planning through minimization of total potential energy," *Automation in Construction,* vol. 31, pp. 92-102, 2013/05/01/ 2013.

[10] X. Ning, J. Qi, and C. Wu, "A quantitative safety risk assessment model for construction site layout planning," *Safety Science,* vol. 104, pp. 246-259, 2018/04/01/ 2018.

[11] P. Alanjari, S. RazaviAlavi, and S. AbouRizk, "Hybrid genetic algorithm-simulation optimization method for proactively planning layout of material yard laydown," *Journal of Construction Engineering and Management,* vol. 141, no. 10, p. 06015001, 2015.

PASSIVE DESIGN FEATURES FOR ENERGY EFFICIENT RESIDENTIAL BUILDING IN HOT CLIMATE

[a] Khushbakht, [b] Alina Mahmood
a: Department of Architectural Engineering and Design, University of Engineering and Technology, Main GT Road-54890, Lahore, Pakistan, khushbakht9@hotmail.com
b: Department of Architectural Engineering and Design, University of Engineering and Technology, Main GT Road-54890, Lahore, Pakistan, alinakhan@live.com

Abstract- The rapidly growing use of energy has raised concerns for depleting energy resources and the resulting heavy environmental impacts. The contribution from the buildings towards energy consumption has steadily increased over the past few decades. Growth in the population, increase in the use of technology, increasing demand for building services, enhanced comfort levels, as well as increase in the time spent inside the buildings depicts an upward trend in energy demand. For this reason, energy efficiency in building sector is of prime importance today. The reduction in energy consumption in buildings can be achieved by simple methods and techniques such as using passive design features and renewable resources. Climate responsive design of buildings and energy efficient systems and technologies such as passive solar systems can reduce the energy demand in buildings. This research is aimed to make contribution in the designing of energy-efficient residential buildings. This study provided guidelines for designing the energy-efficient residential building with passive design features and suggested environmental friendly materials in the context of Rahim Yar Khan, Pakistan. A model house was designed with passive design features and using climate responsive design strategies, evaluated with Ecotect software to analyze the efficiency of suggested passive design features which showed promising results in terms of energy efficiency.

Keywords- Energy-efficient Buildings, Passive Design, Renewable Resources, Residential Building Design

1 INTRODUCTION

Energy is considered to be the life line of any economy, the most vital instrument of socio-economic development and has been recognized as one of the most important strategic commodities. One of the opportunity costs of civilization is increase in the amount of consumption of energy per capita per year [1]. The turning of the world into a global village with modern technologies and their rapidly increasing demand for energy indicates that energy will be one of the biggest problems of the world in the future [2]. This requires use of the alternative sources of energy preferably renewable resources along with the economical utilization of present energy sources [3].

Pakistan is rapidly urbanizing and it is expected that over 40 million more people will be living in urban areas in Pakistan by the year 2025 [4]. This represents a tremendous leap from traditional buildings to new dwelling with more mechanical systems and less passive design features. Many parts of the country face temperatures over 40 degree Celsius in summers. Pakistan has been facing the challenge of inverse energy supply and demand scenarios resulting in load shedding periods in the summer months [5]. This challenge can be overcome by designing buildings with green materials and technologies to reduce operational costs, reliance on electricity and enhance human comfort [6]. Pakistan's energy producing resources are still developing. There has always been an energy crisis in Pakistan due to high energy demand in peak summer months and low supply of electricity. This is a consequence of no serious efforts being made to install new power generation plants. Some of the significant constraints leading to severe energy shortage are; increase in population, circular debt, weak financial position of energy companies, falling gas production, high dependence on oil/gas (over 80%), and low exploitation of indigenous coal and hydel resources, unutilized power generation capacity [7].

Various researchers have worked on the energy saving potential of architectural design by incorporating passive design features. Building plan (shape), envelope, orientation [8], type of glazing were used as passive design features for building design in hot climate which showed considerable saving in energy and reduced the building cooling loads [9]. In one study, architectural design features such as building orientation, shape and complexity of the building plan and the type of glazing used in windows were found to have maximum impact on cooling loads in hot climate [10]. Atrium is another such example which has shown promising results in terms of natural lighting and energy saving up to 15.7% [7].

The use of energy in the residential sector is increasing day by day [11]. According to Hydrocarbon Development Institute of Pakistan, in the total consumption of electricity, the share of household, commercial and other government sector has increased while share of industrial and agriculture sector has decreased over 1993-94 to 2011-12. According to Pakistan Water & Power Development Authority (WAPDA), among all the consumers of electrical power, domestic consumers are consuming electricity at the highest level. There is lot of potential for energy conservation in the domestic sector of Pakistan. In order to conserve energy at domestic sector, it is the important to design energy efficient residential buildings [12]. This work demonstrates the dire need to rely more on passive design features in residential building design in hot climate (Rahim Yar Khan city of Pakistan) to minimize the energy consumption. The climate analysis of Rahim Yar Khan was performed followed by the site analysis. A study was conducted on a residential colony of Rahim Yar Khan to analyze the passive design features used in residential buildings. The studied features were then utilized in the design of a model house incorporating suitable materials according to the climate. Energy analysis of the model house was performed through Ecotect software. The results show that the applied passive design techniques are effective during daytime, during extreme temperatures, in the summer season. But, they will create slight uncomfortable conditions at mid-night; that would be balanced by night-purge cooling effect. The designed shading devices are effective in controlling the heat gain through windows. The lighting analysis performed showed maximum admittance of natural light through openings, which will reduce dependence on artificial light. Hence the study showed promising results and can be utilized to minimize energy consumption in residential sector by the use of passive features in building design.

2 PROBLEM STATEMENT AND RESEARCH AIM

In Rahim Yar Khan, large infrastructure development has been seen during the recent years. Many housing societies are being developed on the outskirts of Rahim Yar Khan city. All this new residential development will cause the energy consumption to rise. Due to increase in urban population and improvement in living standards, the consumption of electricity is increasing by residential sector. Air conditioner usage in the residential buildings, particularly in hot climate, has tremendously increased the energy demands.

By observing many residential buildings in Rahim Yar Khan, it is concluded that buildings are not designed with the aim of energy conservation. The orientation of buildings is not given due importance in the design and most buildings are constructed without proper insulation, with large window-to-wall ratio (WWR), with extensive use of glass, with windows having no appropriate shading. This results in additional heating/cooling loads. Designs of residential buildings are not responsive to the requirements of climate. Dependence on artificial lighting and mechanical systems is common in buildings. Interruptions in the supply of power due to power deficit is a big problem. As the residential buildings are not designed in accordance to the climate, they fail to take advantage from natural climatic features. They become extremely uncomfortable in harsh weather conditions, particularly during periods of load-shedding. It seems that architects are not aware how they can design energy-efficient buildings. They lack in knowledge about basics of energy-efficient building design. On the other hand, developers and clients stress that residential buildings must be designed with maximum space utilization resulting in project economy. They cannot apply energy efficient building techniques independently. They have to convince the developers and clients first.

This study was particularly aimed at; suggesting passive design features for the residential buildings of Rahim Yar Khan (for hot climate) to make them energy-efficient in the context of hot climate; suggesting suitable local, energy-efficient and eco-friendly materials for different building elements; designing a model house by incorporating the suggested passive design features and then evaluating the building for thermal analysis by using Ecotect software. A case study is used to demonstrate the resulting benefits of passive design strategies. Based on the present energy situation, construction practices, increase in number of residential buildings, change in the life style, it is essential to evolve energy-efficient building designs. Passive design of buildings should be first and foremost preference rather than relying completely on active means. This shift of attitude towards energy conservation will help in saving the depleting energy resources. There is a lot of potential for energy conservation in residential sector. The research will contribute in this reference in designing an energy efficient house on small scale. This study can help the stakeholders of the building construction industry including designers, evaluators, building control agencies and energy professionals to put additional efforts to produce more passive design buildings to reduce the burden on the end consumer by reducing energy consumption in residential buildings. The study will also provide guidelines to enable the architects in the design of energy-efficient houses in Rahim Yar Khan.

3 RESEARCH METHODOLOGY

The main objective of the research was to design a model energy–efficient house for the hot climate. To find out what kind of passive design strategies have been incorporated in the residential buildings of Rahim Yar Khan, an observational study of a residential colony was carried out. The architectural features which were fabricated in the houses for protecting the indoor environment from harsh weather conditions (extreme heat or cold) were studied. Whole design process was followed for designing a model energy-efficient house [13], which included the following steps; climate analysis of Rahim Yar Khan, site analysis [14], house design with passive design strategies and passive design elements, selection of suitable materials, analysis [15] of the house designed through the Ecotect software [10].

4 DATA COLLECTION AND ANALYSIS

The climatic data of Rahim Yar Khan City is obtained from the laboratory of Fatima Fertilizer Company Limited, located in Goth Machi, Sadiqabad, where weather conditions are monitored on daily basis. The climate of Rahim Yar Khan is mostly hot and dry in summer season. In winter season, the weather gets cold, dry and pleasant. The warmest month of the year is June. The maximum temperature reaches above 45°C. In January, the average temperature is 13.3 °C. The summer season is longer than the winter season. The summer season starts from April and it continues till the month of October. November to March are considered as months of winter season. The driest month is October with 1 mm rain. Mostly, rainfall occurs in the month of August, around 27 mm. The occurrence of dust storms is very common in summer (May/June). The average annual temperature in Rahim Yar Khan is 26.2°C. So, climate of Rahim Yar Khan can be classified as Hot and Dry.

To find out what kind of passive design strategies have been incorporated in the residential buildings of Rahim Yar Khan, an observational study of a residential colony was carried out. The architectural features which were used in the houses for protecting the indoor environment from harsh weather conditions (extreme heat or cold) were studied. This observational study was analyzed on the basis of theory of Climatic Responsive Design. Problems found during the study are as follows; the orientation is not given any due consideration; the shades which have been provided on the windows are given mainly for aesthetic purpose and they don't serve the purpose of shading, which results in additional heating /cooling loads; the houses are not designed according to the climate; extensive use of glass was seen; reflective type of glass has also been used. For designing the model energy-efficient house with passive design features, a plot from housing society 'Abbassia town' was selected. Abbassia town is a large, newly developed housing society located in the outskirts of Rahim Yar Khan City. The copy of the bye-laws for the buildings was first obtained from the TMA Rahim Yar Khan.

5 RESIDENTIAL BUILDING DESIGN

Whole design process was followed for designing a model energy-efficient house, which included the following steps; climate analysis; site analysis; house design with passive design strategies and passive design elements; selection of suitable materials; analysis of the house designed through the software Ecotect [16]. An actual site was selected from a newly developed housing society in Rahim Yar Khan for designing a model house. Climate data was collected as in Figure 1 and site analysis was done in the start of the deign process. Based on the theoretical knowledge; a model house was designed with focus on passive design features with Ecotect software as in Figure 2. The designed house was then analyzed though the software Ecotect, to demonstrate the benefits resulting from incorporation of suggested passive features [17]. Use of alternate renewable source of energy was also explored in the local context. Suitable eco-friendly materials have also been proposed and discussed in detail. A two-story house has been designed.

From the climate analysis, it can be seen that there is a difference of about 20°C between day-time and night-time temperatures. In summers, the temperature reaches above 45°C and summers are longer than the winter months. The main factor to tackle in the energy-efficient design of the house will be the cooling load. Concept of passive design has been incorporated into the house plan, with passive cooling and passive ventilation strategies. The main aim was to design a house in such a way as to reduce the heat gain in extremely high temperatures and ultimately the cooling load. Following strategies have been used while designing an energy-efficient house; air movement; cooling breezes; convective air movement; radiative cooling. A lawn has been designed on the North side as coolth pond. Sunken garden with depth 3 feet has been given, which is a classic example of a coolth pond, into which the cooler air, during the night-time will descend. Garden walls will act as pond walls. In this way, the cooler air will enter the house through openings, at night. The direction of the wind is North-South during the summer months and dust storms are common during this season. As a lawn is designed at the North side, the air will be passed over naturally planted ground cover, which will reduce the dust levels.

UN-HABITAT in partnership with Ministry of Environment, Capital Development Authority (CDA, ENERCON National Energy Conservation Centre (ENERCON) and manufacturers and suppliers conducted an energy efficient housing project which has been used for the selection of materials for the model house. Materials are proposed for the designed house based on following factors; availability, maintenance, energy-efficiency, impacts on natural environment, durability, recyclable and obtained from renewable resources. Clay bricks were proposed for walls as they are locally fabricated in Rahim Yar Khan [18]. Double-glazed windows [8] with low-solar-gain, low-E glass with argon gas fill is proposed for the windows [19]. Polyvinyl chloride (PVC) frames has high R–value (Resistance value) and low maintenance (high performance commercial buildings). So, PVC frames are proposed for the window frames [20]. Cavity walls are proposed for walls [21]. Polystyrene (Jumbolon) with plain concrete screed is selected as proposed insulation technique for the roof slab of the designed house [19].

The delimitations of this work include; the study was delimited to residential buildings; as multistory-apartments/flats are not common in Rahim Yar Khan, the study was delimited to separate units that is single story, multi-story houses; the study was confined to the energy use in the operational phase of the house; the study was restricted to suggesting passive design strategies for new houses.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	30.5 (86.9)	35.5 (95.9)	41.4 (106.5)	45.8 (114.4)	47.3 (117.1)	47.5 (117.5)	44.2 (111.6)	42.9 (109.2)	42.3 (108.1)	40.4 (104.7)	36.8 (98.2)	31.3 (88.3)	47.5 (117.5)
Average high °C (°F)	23.0 (73.4)	25.5 (77.9)	31.8 (89.2)	38.2 (100.8)	41.7 (107.1)	41.6 (106.9)	37.8 (100)	36.6 (97.9)	36.7 (98.1)	36.2 (97.2)	30.7 (87.3)	25.3 (77.5)	33.76 (92.78)
Daily mean °C (°F)	14.3 (57.7)	17.1 (62.8)	23.4 (74.1)	30.2 (86.4)	34.3 (93.7)	35.2 (95.4)	32.8 (91)	31.7 (89.1)	30.7 (87.3)	27.7 (81.9)	21.5 (70.7)	16.1 (61)	26.25 (79.26)
Average low °C (°F)	5.6 (42.1)	8.8 (47.8)	15.0 (59)	22.1 (71.8)	26.8 (80.2)	28.8 (83.8)	27.7 (81.9)	26.8 (80.2)	24.7 (76.5)	19.1 (66.4)	12.1 (53.8)	6.9 (44.4)	18.7 (65.66)
Record low °C (°F)	−0.9 (30.4)	−2.7 (27.1)	3.7 (38.7)	12.0 (53.6)	15.8 (60.4)	19.8 (67.6)	20.3 (68.5)	20.4 (68.7)	16.3 (61.3)	10.2 (50.4)	3.3 (37.9)	−0.9 (30.4)	−2.7 (27.1)
Precipitation mm (inches)	5.7 (0.224)	7.8 (0.307)	6.3 (0.248)	11.9 (0.469)	15.9 (0.626)	33.0 (1.299)	91.1 (3.587)	82.6 (3.252)	40.8 (1.606)	10.1 (0.398)	1.9 (0.075)	3.0 (0.118)	310.1 (12.209
Avg. precipitation days	0.8	1.0	1.5	0.9	2.6	3.2	6.6	5.6	3.0	0.6	0.3	0.5	26.6
% humidity	49	43	34	25	27	39	58	61	52	36	40	48	42.7

Figure 39 Climate data of Bikaner-India (reference data for Rahim Yar Khan, Pakistan)

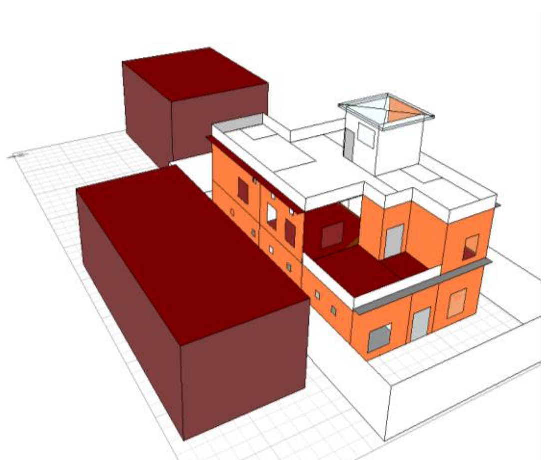
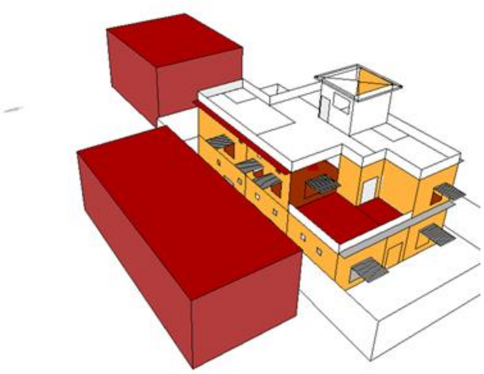


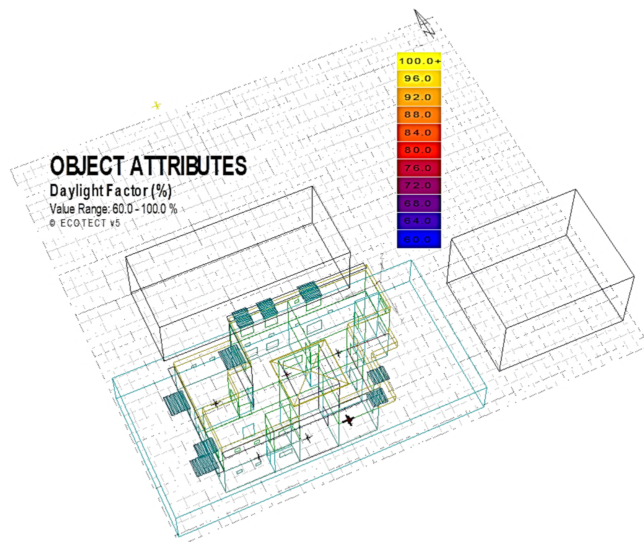
Figure 40 Model of house designed with adjacent houses

6 RESULTS

The results showed that the applied Passive design techniques will be effective during day-time, during extreme temperatures, in the summer season. But they will create slight uncomfortable conditions at mid-night that would be balanced by night-purge cooling effect. The designed shading devices will be effective in controlling the heat gain through windows. The lighting analysis shows maximum admittance of natural light through openings, which will reduce dependence on artificial light. The daylight analysis was done with Ecotect after designing the shading devices for the windows as presented in Figure 3 (a) and (b) respectively. Whereas, Figure 4 depicts the hourly temperature graph which shows the internal temperatures of all visible thermal zones in the model over a 24-hour period. It has been calculated for the hottest day (average) that is, May 16th, for all the visible zones. The graph shows that during the day time, the temperatures inside the zones will be less than the outside temperature. Here, the graph also depicts that during mid-night; inside temperatures are more than the outside temperature, which is due to the heat gained by the fabric during the day. Then the night-time cooling will cool the mass and will help to lower the inside temperatures. The daylight analysis was done with Ecotect after designing the shading devices for the windows as presented in Figure 3 (a) and (b) respectively. Figure 3 (b) shows that the daylight factor for inner zones is more than 80% that will reduce the use of artificial lighting.



(a)



(b)

Figure 41 (a) Shading devices designed for windows of house through Ecotect (b) Ecotect daylight analysis

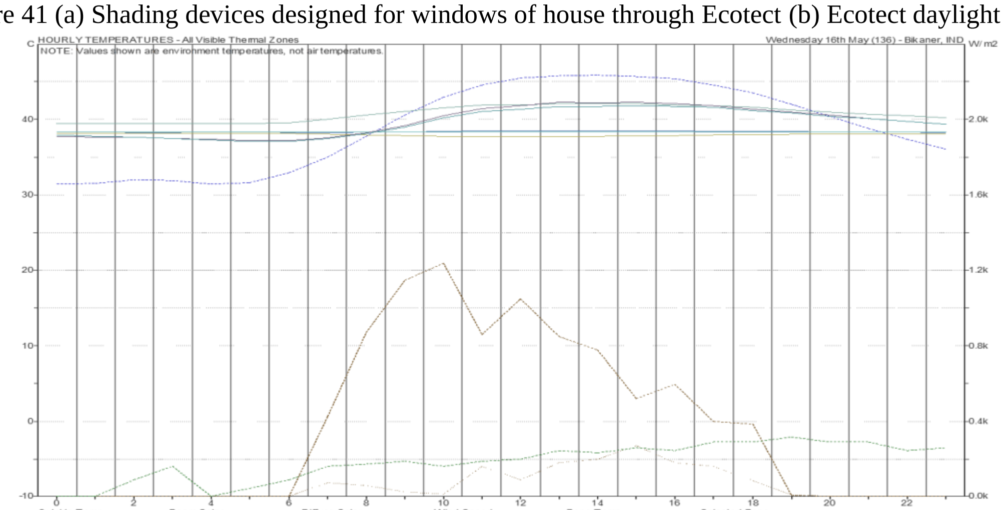


Figure 42 Hourly temperature analysis with Ecotect

7 PRACTICAL IMPLEMENTATION OF RESEARCH

The house with passive design features was modeled and analyzed in Ecotect software. The model house was designed with carefully selected materials based on the climate analysis of Rahim Yar Khan city and the site analysis. This analysis can be performed by the designer and the energy professionals by incorporating new materials and by adding or removing the various passive design features as per the requirements of the stakeholders of the building construction industry. The results can depict the amount of energy saved by relying more on passive means rather than active means. These results can be utilized as a benchmark for designing other buildings in various different climates by incorporating the relevant weather data files in Ecotect.

8 CONCLUSION AND RECOMMENDATIONS

The traditional house constructed with lime mortar and lime plaster, having a central courtyard, verandahs for passive ventilation, thick and massive walls acting as insulation, clay roof with white washing providing additional insulation and reflectance properties, double height ceilings with ventilators at the top to allow accumulated heat to escape provided a comfortable environment without relying much on mechanical means. However, with the advancement of technologies and adoption of air-conditioner and a sealed building system with fixed windows; the traditional design concepts and passive means were gradually discarded. Designers can now reach for the energy solutions to climate modification with ease, passing on running costs to consumers and designing buildings without concern. This present approach of designers has resulted in increase of energy consumption by buildings. The results of this study showed that the applied passive design techniques will be effective during day-time, during extreme temperatures, in the summer season. But they will create slight uncomfortable conditions at mid-night which would be balanced by night-purge cooling effect. The designed shading devices will be effective in controlling the heat gain through windows. The lighting analysis shows maximum admittance of natural light through openings, which will reduce dependence on artificial light.

In order to design a building, which is responsive to the climate of the area and operate without much dependence on artificial means, the process of designing such building should include following steps; study of climate of the area where site for the building is located; study of the site of the building; identifying passive design features ,suitable for the site specific climate; selection of suitable, local and recyclable materials with low embodied energy and integrating the identified features effectively in the building design.

ACKNOWLEDGMENT

The authors would like to thank the concerned persons from laboratory of Fatima Fertilizer Company Limited who helped in collecting weather data for this research. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] S.-H. Yoon, S.-Y. Kim, G.-H. Park, Y.-K. Kim, C.-H. Cho, and B.-H. Park, "Multiple power-based building energy management system for efficient management of building energy," Sustainable Cities and Society, vol. 42, pp. 462-470, 2018/10/01/ 2018.

[2] L. J. Underhill, C. W. Milando, J. I. Levy, W. S. Dols, S. K. Lee, and M. P. Fabian, "Simulation of indoor and outdoor air quality and health impacts following installation of energy-efficient retrofits in a multifamily housing unit," *Building and Environment*, vol. 170, p. 106507, 2020/03/01/ 2020.

[3] N. Mazhar, R. D. Brown, N. Kenny, and S. Lenzholzer, "Thermal comfort of outdoor spaces in Lahore, Pakistan: Lessons for bioclimatic urban design in the context of global climate change," *Landscape and Urban Planning*, vol. 138, pp. 110-117, 2015/06/01/ 2015.

[4] M. E. Biresselioglu, M. H. Demir, A. Rashid, B. Solak, and E. Ozyorulmaz, "What are the preferences of household energy use in Pakistan?: Findings from a national survey," *Energy and Buildings*, vol. 205, p. 109538, 2019/12/15/ 2019.

[5] M. A. Khan and U. Ahmad, "Energy demand in Pakistan: a disaggregate analysis," *The Pakistan Development Review*, pp. 437-455, 2008.

[6] Y.-H. Chang, P.-H. Huang, B.-Y. Wu, and S.-W. Chang, "A study on the color change benefits of sustainable green building materials," *Construction and Building Materials*, vol. 83, pp. 1-6, 2015.

[7] F. Sher, A. Kawai, F. Güleç, and H. Sadiq, "Sustainable energy saving alternatives in small buildings," *Sustainable Energy Technologies and Assessments*, vol. 32, pp. 92-99, 2019/04/01/ 2019.

[8] M. V. Shoubi, M. V. Shoubi, A. Bagchi, and A. S. Barough, "Reducing the operational energy demand in buildings using building information modeling tools and sustainability approaches," *Ain Shams Engineering Journal,* vol. 6, no. 1, pp. 41-55, 2015/03/01/ 2015.

[9] A. Al-Saggaf, M. Taha, T. Hegazy, and H. Ahmed, "Towards Sustainable Building Design: The Impact of Architectural Design Features on Cooling Energy Consumption and Cost in Saudi Arabia," *Procedia Manufacturing,* vol. 44, pp. 140-147, 2020/01/01/ 2020.

[10] A. Al-Saggaf, H. Nasir, and M. Taha, "Quantitative approach for evaluating the building design features impact on cooling energy consumption in hot climates," *Energy and Buildings,* vol. 211, p. 109802, 2020/03/15/ 2020.

[11] S. Gou, V. M. Nik, J.-L. Scartezzini, Q. Zhao, and Z. Li, "Passive design optimization of newly-built residential buildings in Shanghai for improving indoor thermal comfort while reducing building energy demand," *Energy and Buildings,* vol. 169, pp. 484-506, 2018/06/15/ 2018.

[12] C. Gargari, C. Bibbiani, F. Fantozzi, and C. A. Campiotti, "Environmental Impact of Green Roofing: The Contribute of a Green Roof to the Sustainable use of Natural Resources in a Life Cycle Approach," *Agriculture and Agricultural Science Procedia,* vol. 8, pp. 646-656, 2016/01/01/ 2016.

[13] K. M. Aldali and W. S. Moustafa, "An attempt to achieve efficient energy design for High-Income Houses in Egypt: Case Study: Madenaty City," *International Journal of Sustainable Built Environment,* vol. 5, no. 2, pp. 334-344, 2016/12/01/ 2016.

[14] F. Faizi, M. Noorani, A. Ghaedi, and M. Mahdavinejad, "Design an Optimum Pattern of Orientation in Residential Complexes by Analyzing the Level of Energy Consumption (Case Study: Maskan Mehr Complexes, Tehran, Iran)," *Procedia Engineering,* vol. 21, pp. 1179-1187, 2011/01/01/ 2011.

[15] Q. Wu and W. Gao, "Research on the Design of Ecological Energy-saving Building Based on the Climate Condition of Hangzhou," *Procedia - Social and Behavioral Sciences,* vol. 216, pp. 986-997, 2016/01/06/ 2016.

[16] L. Yang, B.-J. He, and M. Ye, "Application research of ECOTECT in residential estate planning," *Energy and Buildings,* vol. 72, pp. 195-202, 2014/04/01/ 2014.

[17] A. Utama and S. H. Gheewala, "Life cycle energy of single landed houses in Indonesia," *Energy and Buildings,* vol. 40, no. 10, pp. 1911-1916, 2008/01/01/ 2008.

[18] R. E.-D. Hamed, "Harmonization between architectural identity and energy efficiency in residential sector (case of North-West coast of Egypt)," *Ain Shams Engineering Journal,* vol. 9, no. 4, pp. 2701-2708, 2018/12/01/ 2018.

[19] M. Khoukhi, "The combined effect of heat and moisture transfer dependent thermal conductivity of polystyrene insulation material: Impact on building energy performance," *Energy and Buildings,* vol. 169, pp. 228-235, 2018/06/15/ 2018.

[20] A. Gustavsen, S. Grynning, D. Arasteh, B. P. Jelle, and H. Goudey, "Key elements of and material performance targets for highly insulating window frames," *Energy and Buildings,* vol. 43, no. 10, pp. 2583-2594, 2011/10/01/ 2011.

[21] D. Alterman, T. Moffiet, S. Hands, A. Page, C. Luo, and B. Moghtaderi, "A concept for a potential metric to characterise the dynamic thermal performance of walls," *Energy and Buildings,* vol. 54, pp. 52-60, 2012/11/01/ 2012.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

ANALYZING FACTORS INFLUENCING CONSTRUCTION LABOR PRODUCTIVITY USING FUZZY ANALYTICAL HIERARCHY PROCESS (FAHP)

[a] Muhammad Nizar Alam, [b] Kausar Rafique, [c] Riaz Ul Haq
a: Postgraduate student, Department of Construction Engineering and Management, National University of Science and Technology (NUST), Risalpur, Pakistan, muhammadnizar155@gmail.com
b: Postgraduate student, Department of Civil Engineering, Iqra National University Peshawar, kausarkhattak1996@gmail.com
c: Corresponding author, Postgraduate student, Department of Construction Engineering and Management, National University of Science and Technology (NUST), Risalpur, Pakistan, riaz85264@gmail.com

Abstract- The construction sector contributes an indispensable role in the country economy. Among many other factors the significance of the construction labour production cannot be denied. The cost of labor comprises of 30-50% of the project costs. To improve the productivity of the construction labor, it needs to explore the factors that affect the productivity. This study is conducted to analyze the factors that affect the construction labor productivity in developing country like Pakistan. The factors were tabulated after studying detailed literature about the topic of discussion. The factors were then analyzed by taking the experts responses on a scale of 1-9. The fuzzy Analytical Hierarchy Process (Fuzzy AHP) is used to rank the factors considering the expert responses. The results reveal the "leadership and effectiveness" of the managing personals on site is the main factors that affect the labor productivity. The outcomes of this study will be used as an input of making polices for improving the labour productivity in construction industry.

Keywords- Labor Productivity, Factors affecting, Fuzzy AHP

1 INTRODUCTION

The growth of the construction sector is mainly related with productivity, and the productivity is mainly dependent on labor performance. Labor cost comprises of about 30 to 50% of the overall project's cost (Jarkas & Bitar, 2011). In construction industry, we can minimize the cost by working out the productivity. In evolved and underdeveloped countries productivity play an important role (Alaghbari, Al-Sakkaf, & Sultan, 2019).

Defining the success of a project, labor productivity plays a key role (Mahamid, 2014) . Though, many factors affects labour productivity. It comprise of factors related to materials, labour, tools and equipment, political, construction methods, environment and financing.

2 RESEARCH PROBLEM

One of the key reasons of failing the projects in terms of budget and schedule is because of poor labour productivity. So, to evolve this reason there is a need of management attention (Alaghbari et al., 2019). The project success within time and given budget is a very important task. It helps in minimizing the conflicts between the stakeholders. It would also increase profits, contribute to the GDP and development of construction industry(Al-Najjar, 2008). To apprehend these benefits we need to improve the labour work profitability in development.

3 RESEARCH OBJECTIVES

- *To become explore the factors influencing labour productivity.*
- *To formulate guidelines for improving construction overall performance.*

4 LITERATURE REVIEW

Productivity is the rate of output against per unit time. Researchers have found that in construction industry, man power is highly consumed which directly effects project cost, time over run and many other factors (Hickson & Ellis, 2014). Labour productivity is a difficult parameter and is challenging to measure but here we are not discussing this issue, we will only study the reasons effecting labors productivity in Pakistan.

4.1 *Pakistan construction industry*

In past, Government of Pakistan did not compile the construction industry data due to which the industry failed to give better output. Now, construction industry is declared officially a separate industry by ministry of Pakistan. As there is war and terror, and the nation is going on through financial and force crises, the Planning Commission has assessed horribly that from declining performance of labours from the last two decades, the country economy is going down. The low labor productivity is the most crucial problem for the economy (Muzamil & Khurshid, 2014). According to (Shah & Ahad, 2017) construction industry accounts for six to nine percent of the GDP. While in Pakistan it adds only two and a half percent to the GDP.

4.2 *Construction labour productivity in Pakistan*

In Pakistan construction industry suffers from many problems which affect labor productivity. Thus, the efficiency of labour play a huge role in construction industry. Efficiency of labour is affected by several factors in projects. By reviewing the literature a lot of different factors exist in different countries. According to Pakistan our cultural practices is little bit different and experts have put efforts in identifying those factors. Experience members firstly, determined 54 labour factors that influence development work efficiency. After that, Questionnaire of 54 factors is distributed on 12 members. Client, consultant, contractor and academia participate three from each respectively. They suggest 15 factors out of those 54 factors. Hierarchy structure figure-1 summaries the important influencing labour productivity factors in construction industry which is suggested by the researchers in many countries. In the research, (Muzamil & Khurshid, 2014), mention that there is limited study was conducted in Pakistan regarding construction labour productivity. Another study shows that, in Pakistan there is no significant research conducted to find out and give solutions to factors which affect the productivity of labours in various way in construction industry of Pakistan (Shah & Ahad, 2017).
There are many factors and sub factors were established throughout the world and it may vary region to region because of the environment, culture and economy (Polat & Arditi, 2005). Along these lines their impact on cost and time of task likewise varies as for changed ecological, financial, security and different issues of a country (Muzamil & Khurshid, 2014).

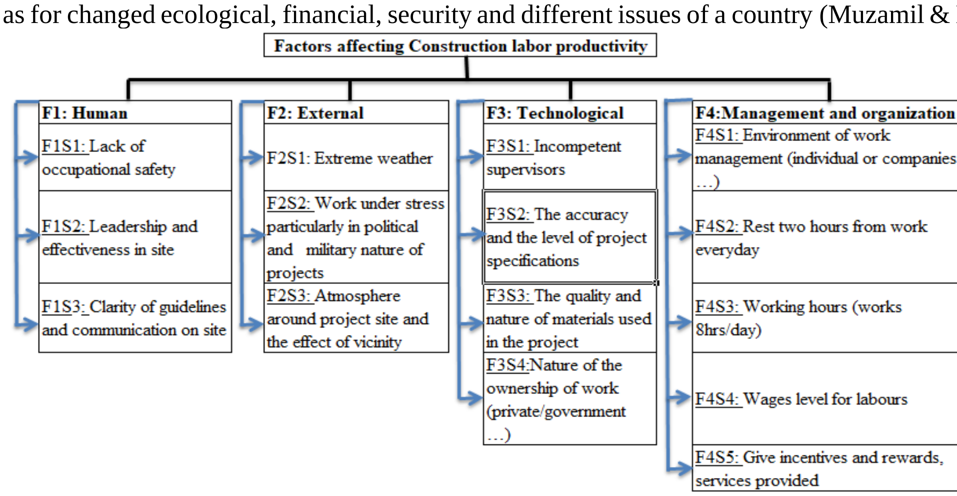


Figure 1: Hierarchy of the study

5 RESEARCH METHODOLOGY

To meet the research objectives firstly, we review the literature and identified the variables that influence work profitability. After that we design a questionnaire and determine the most reliable factors that pressurize the construction industry of Pakistan to give much attention regarding labor productivity. The client, consultant, contractor and the academia involves by fulfilling the questionnaire. In this survey total twelve (12) members fulfill the questionnaire, three from each respectively. And in the last phase we rank the variables that influence work efficiency, for this we use Fuzzy AHP technique. The figure-2 shows the research methodology flowchart.

5.1 Analytical Hierarchy process (AHP)

To make appropriate results of the criteria this survey is planned to assemble and examine decisions from participants. Analytical Hierarchy process uses a pairwise evaluation technique to make weightings (ratio scales) for criteria, instead of other simple ranking by other relative index's (Strehlow et al., 2003). Moreover, the application of AHP does not involve difficult arithmetic calculations; it can easily be understood without problems.

5.2 Fuzzy theory

The main purpose for the creation of this idea was to represent ambiguity precisely and to make available formal tools for dealing with the vagueness nature to many problems (Asad, Kermani, & Hora, 2015). Triangular or trapezoidal fuzzy numbers are popular (Guha & Chakraborty, 2011).In this work our focus is on the use triangular fuzzy number, fuzzy AHP. Following Table shows its Scale (Koulinas, Marhavilas, Demesouka, Vavatsikos, & Koulouriotis, 2019).

Table 1- Standard scale

Table of labels associated with Saaty's model (Lamata, 2004).

Definition	Saaty's Scale	Triangular number
Ai and Aj are equally important	1	[1,1,1]
Ai is moderately more important than Aj	3	[2,3,4]
Ai is strongly more important than Aj	5	[4,5,6]
Ai is very strongly more important than Aj	7	[6,7,8]
Ai is extremely more important than Aj	9	[8,9,9]
The scales 2,4,6, and 8 are also used and represent compromises among the tabulated scale	2,4,6, and 8	In the same way

5.3 Fuzzy AHP

As ambiguity and doubt are most joint conditions in lot of decision creation issues, a decent result making model wants to tolerate ambiguity (Asad et al., 2015). Linguistic values membership functions are generally categorized by Triangular Fuzzy Numbers, are suggested to estimate best evaluations as a replacement for of conventional numerical correspondence approach, due to the fact the ambiguous linguistic approach can take the reliable rating mind-set of judgment makers under consideration (Liang & Wang, 1994). via Analytical hierarchy process, the significance of numerous catogories is acquired from a procedure of paired assessment, where the significance of the elements or categories of drivers of intangible belongings are matched two-on-two in a hierarchic shape (Sun, 2010).

Thus, the fuzzy- Analytical hierarchy process method had better and more appropriate than conventional Analytical hierarchy process in practical, where an ambiguous pairwise assessment environment exists (Lee, Chen, & Chang, 2008). Step 1: In the first step, pairwise comparison matrices of factors/criteria of the hierarchy structure within the dimensions is develop. Allocate linguistic variables to the pairwise assessments by means of asking that which one is more important of each 2 dimensions, as following matrix A

$$A' = \begin{bmatrix} 1 & a'_{12} & \cdots & a'_{1n} \\ a'_{21} & 1 & \cdots & a'_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a'_{n1} & a'_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & a'_{12} & \cdots & a'_{1n} \\ 1/a'_{12} & 1 & \cdots & a'_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a'_{1n} & 1/a'_{2n} & \cdots & 1 \end{bmatrix} \quad (1)$$

Where $\tilde{a}_{ij} = \begin{cases} \tilde{9}^{-1}, \tilde{8}^{-1}, \tilde{7}^{-1}, \tilde{6}^{-1}, \tilde{5}^{-1}, \tilde{4}^{-1}, \tilde{3}^{-1}, \tilde{2}^{-1}, \tilde{1}^{-1}, \tilde{1}, \tilde{2}, \tilde{3}, \tilde{4}, \tilde{5}, \tilde{6}, \tilde{7}, \tilde{8}, \tilde{9}, \ 1, & i \neq j \\ 1 & i = j \end{cases}$

Step 2: For finding Fuzzy Geometric mean and Fuzzy weights of every factor we use Geometric Mean Technique (Srdjevic et al., 2013).

$$r'_i = \left(a'_{i1} * \cdots * a'_{ij} * \cdots * a'\right)^{1/n} \quad (2)$$

$$\widetilde{W}_1 = \tilde{r}_1 * (\tilde{r}_1 + \tilde{r}_2 + \tilde{r}_3 + \tilde{r}_4 + \tilde{r}_5 + \tilde{r}_6)^{-1} \quad (3)$$

Step 3: For finding the overall weight we use the formula (Sun, 2010).

$$BNP_{w_1} = [(U_{w_1} - L_{w_1}) + (M_{w_1} - L_{w_1})]/3 + L_{w_1} \quad (4)$$

Adding fuzzy numbers (+):

$$A' + B' = (l_1, m_1, u_1) + (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad (5)$$

Multiplying TFNs (*)

$$A' * B' = (l_1, m_1, u_1) * (l_2, m_2, u_2) = (l_1 l_2, m_1 m_2, u_1 u_2) \quad (6)$$

Triangular Fuzzy number subtraction (-)

$$A' - B' = (l_1, m_1, u_1) - (l_2, m_2, u_2) = (l_1 - l_2, m_1 - m_2, u_1 - u_2) \quad (7)$$

Division of triangular FNs (/): $A'/B' = (l_1, m_1, u_1)/(l_2, m_2, u_2) = \left(\frac{l_1}{u_2}, \frac{m_1}{m_2}, \frac{u_1}{l_2}\right)$ (8)

Inverse of the munbers $(A')^{-1} = (l_1, m_1, u_1)^{-1} = \left(\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}\right)$ (9)

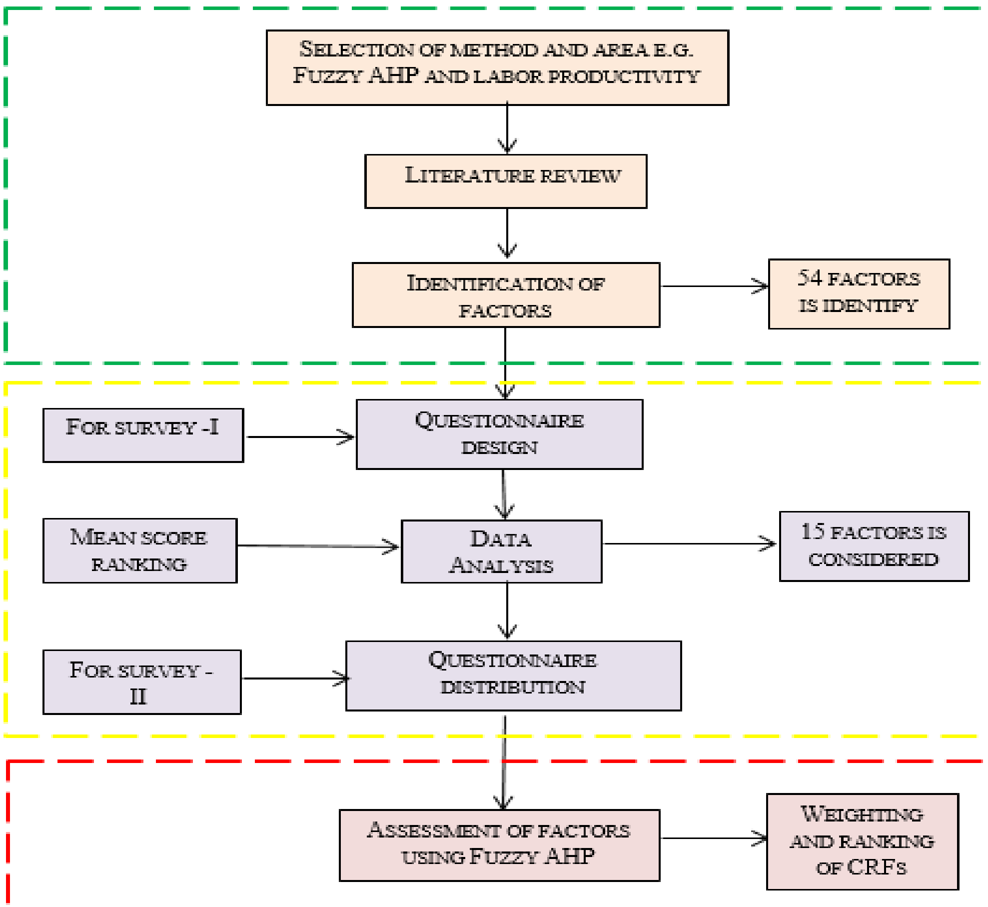


Figure 2: Hierarchy of the study

6 Results

To improve the construction labor productivity of Pakistan we have to focus on the determined factors as shown in table 2. Out of fifteen factors, the top factors that affect construction labor productivity are 1) leadership and effectiveness in site 2) work under stress particularly in political and military nature of projects 3) atmosphere around project site 4) incentive and rewards also affect and 5) Extreme weather condition.

Table 2- Final results of the fuzzy AHP computations

Main Factors	Overall weight	Percentage (%)	sub-factors	overall weight	Percentage (%)	Ranking
FI	0.15	14.34	F1S1	0.23	22	10
			F1S2	0.494	48	1

			F1S3	0.301	29.4	6
F2	0.17	15.83	F2S1	0.31	30.1	5
			F2S2	0.356	34.8	2
			F2S3	0.354	34.6	3
F3	0.43	40.04	F3S1	0.25	24.4	9
			F3S2	0.218	21	13
			F3S3	0.3	29	7
			F3S4	0.26	25.4	8
F4	0.32	29.79	F4S1	0.224	22	11
			F4S2	0.09	9	15
			F4S3	0.17	17	14
			F4S4	0.219	21	12
			F4S5	0.32	31	4

7 CONCLUSION

By reviewing the literature it is determine that no study is conducted in Pakistan that consider factors affecting construction labour productivity. With the help of linguistic variables Fuzzy AHP can overcome such incompetence. This technique is a more organized and effective method than the other MCDM methods. Hence, fuzzy AHP is an efficient method for coping with the fuzziness of the facts involved in identifying the preferences or results of different decision variables (Sezhian, Muralidharan, Nambirajan, & Deshmukh, 2011). The authors assess different factors; the top most factor that affect construction labour productivity is 'leadership and effectiveness in site 'while in other countries it is different. By improving or mitigating such factors Pakistan construction industry improves labour productivity. By considering these factors farther research may conducted to mitigate the issues in the context of industry 4.0. The author (Poirier, E. A., Staub-French, S., & Forgues, D. 2015) determined in a study that labor productivity is improved in a prefabricated sector ranging from 75% to 240% by using Building information modeling..

ACKNOWLEDGMENT

The authors would like to thank every person/department who helped throughout the research work, particularly Mohsen Mazaheri Asad , Engr. Dr. Rai Waqas Azfar khan and CE&M department NUST Islamabad Pakistan .

REFERENCES

Al-Najjar, J. M. (2008). Factors influencing time and cost overruns on construction projects in the Gaza Strip. Factors Influencing Time and Cost Overruns on Construction Projects in the Gaza Strip.

*Alaghbari, W., Al-Sakkaf, A. A., & Sultan, B. (2019). Factors affecting construction labour pr*oductivity in Yemen. *International Journal of Construction Management*, *19*(1), 79-91.

Asad, M., Kermani, S., & Hora, H. (2015). *A Proposed Framework for Evaluating Student's Performance and Selecting the Top Students in E-Learning System, Using Fuzzy AHP Method.* Paper presented at the Proceedings of the International Conference on Management, Economics and Humanities, Istanbul-Turkey.

Hickson, B. G., & Ellis, L. A. (2014). Factors affecting construction labour productivity in Trinidad and Tobago. *The Journal of the Association of Professional engineers of Trinidad and Tobago*, *42*(1), 4-11.

Guha, D., & Chakraborty, D. (2011). Fuzzy multi attribute group decision making method to achieve consensus under the consideration of degrees of confidence of experts' opinions. *Computers & Industrial Engineering*, *60*(4), 493-504.

Jarkas, A. M., & Bitar, C. G. (2011). Factors affecting construction labor productivity in Kuwait. *Journal of construction engineering and management*, *138*(7), 811-820.

Koulinas, G., Marhavilas, P., Demesouka, O., Vavatsikos, A., & Koulouriotis, D. (2019). Risk analysis and assessment in the worksites using the fuzzy-analytical hierarchy process and a quantitative technique–A case study for the Greek construction sector. *Safety science*, *112*, 96-104.

Lamata, M. T. (2004). Ranking of alternatives with ordered weighted averaging operators. *International Journal of Intelligent Systems*, *19*(5), 473-482.

Lee, A. H., Chen, W.-C., & Chang, C.-J. (2008). A fuzzy AHP and BSC approach for evaluating performance of IT department in the manufacturing industry in Taiwan. *Expert systems with applications*, *34*(1), 96-107.

Liang, G.-S., & Wang, M.-J. J. (1994). Personnel selection using fuzzy MCDM algorithm. European journal of operational research, 78(1), 22-33.

Mahamid, I. (2014). Contractors' perception of risk factors affecting cost overrun in building projects in Palestine. *The IES Journal Part A: Civil & Structural Engineering, 7*(1), 38-50.

Muzamil, A. B., & Khurshid, B. (2014). Analysis of labour productivity of road construction in Pakistan. *International Journal of Engineering and Advanced Technology (IJEAT), 3*(3), 153-159.

Poirier, E. A., Staub-French, S., & Forgues, D. (2015). Measuring the impact of BIM on labor productivity in a small specialty contracting enterprise through action-research. *Automation in construction*, *58*, 74-84.

Polat, G., & Arditi, D. (2005). The JIT materials management system in developing countries. *Construction Management and Economics*, *23*(7), 697-712.

Sezhian, M. V., Muralidharan, C., Nambirajan, T., & Deshmukh, S. (2011). Performance measurement in a public sector passenger bus transport company using fuzzy TOPSIS, fuzzy AHP and ANOVA–a case study. *International Journal of Engineering Science and Technology (IJEST), 3*(2), 1046-1059.

Shah, S. W. A., & Ahad, M. Z. (2017). Factors Affecting Construction Labor Productivity In Peshawar Khyber Pakhtunkhwa (KPK) Pakistan. *Advances in Social Sciences Research Journal, 4*(25).

Srdjevic, Z., Lakicevic, M., & Srdjevic, B. (2013). Approach of decision making based on the analytic hierarchy process for urban landscape management. *Environmental management, 51*(3), 777-785.

Strehlow, K., Werner, N., Berweiler, J., Link, A., Dirnagl, U., Priller, J., . . . Böhm, M. (2003). Estrogen increases bone marrow–derived endothelial progenitor cell production and diminishes neointima formation. *Circulation, 107*(24), 3059-3065.

Sun, C.-C. (2010). A performance evaluation model by integrating fuzzy AHP and fuzzy TOPSIS methods. *Expert systems with applications, 37*(12), 7745-7754.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

DAMAGE ASSESSMENT OF HISTORICAL BUILDINGS: A CASE STUDY OF HISTORIC SHRINE OF MULTAN

[a] Sunera Imtiaz*, [b] Syyed Adnan Raheel Shah, [c] Muhammad Kashif Anwar [d] Mudasser Muneer Khan
[f] Syed Shahid Ali Bukhari
a, f: Department of Building and Architectural Engineering, Bahauddin Zakariya University, Multan.
, Email: sunera_imtiaz@hotmail.com, Shahidbukhari786@hotmail.com
b,c: Department of Civil Engineering, Pakistan Institute of Engineering & Technology, Multan.
Email: adnanshah@piet.edu.pk; kashifanwar723@gmail.com; 2kx5civil114@piet.edu.pk;
d: Department of Civil Engineering, Bahauddin Zakariya University, Multan.
, Email: mudasserkhan@bzu.edu.pk

Abstract- Assessment of safety is very important before taking any prevention decision through qualitative and quantitative data. Qualitative information involves visual examination of structural failure, erosion, and damage, and quantitative data includes a measurable quantity such as laboratory testing, numerical methods, etc. The quantitative data is a comprehensive approach to collecting data that requires expertise as well as takes more time and resources. Hence, there is a need to find out effective approaches for examining the damage level of such structures because there are so many historical landmarks and only a few experts in this area. There are guidelines and checklists are available for designing seismic resistance structures especially for current structures including assessing damage level. However, damage assessment before the hazard is still not common for historical buildings and shrines. This research presents the visual inspection practice for the identification of the damage level of the historical masonry buildings. Based on the assessment results, this study will help specialists to design the high-damage buildings towards the visual inspection.

Keywords- Historical Structures, Masonry, Damage Assessment, Visual Inspection.

1 INTRODUCTION

The most significant aspect of cultural identity is historical structures and monuments. The art and cultural importance of such structures is the source of attraction and used by millions of people for a hundred years. Due to this reason, human duty is to protect historical and cultural buildings for new generations. Many of the existing architectural structures are complex because of constructed from masonry works including bricks, blocks, adobe, and mortar. The taxonomy, design, and layout of the structure, the size of the elements/blocks, the choice of building materials depends on the construction time and cost [1]. Historical structures have faced numerous acts during their lifespan over long periods as they suffered from long-term weakening effects and seismic loads. The description of the historical design depends entirely on both construction time and the cultural history to which it originally belongs, as well as the location. Therefore, there is no benchmark set for the assessment of historical structures[2]. The damage assessment of historical structures is required a versatile team of experts, and different approaches. It is very significant to assess and estimate possible damages for historical masonry buildings caused by natural catastrophic events. However, there are structural codes, standards, and guidelines are exist for new constructions such approaches not used in the safety inspection of historical buildings[3]. It is a challenging task to carry out precise damage evaluation of ancient masonry construction. The data based on qualitative and quantitative is important before taking any treatment decision for safety evaluation. Various surveyors have obtained and documented the qualitative data in the literature from a visual examination of structural failure, disintegration, and erosion. The acquisition of quantitative data involves very complex and difficult procedures that require specialists and consume time and resources. Thus, such approaches only worked on a small number of buildings but primarily used in the final phase of the diagnosis and safety evaluation[4]. However, Historic monumental buildings are original. For assessing the safety condition of such structures, it is very important to define and use different methods and strategies. It is necessary to examine each structure component in its state and consider it as a whole in the assessment process while evaluating structural deterioration and damage[5].

This paper presents an approach of visual inspections for evaluating the damage level of monumental heritage buildings in prone situations. This research focuses on the inspection approach based on an acquisition of visual data and the description of the potential consequence of the inspected structure. Since the work in this area mainly focuses on vernacular architecture, this research focuses on domed and vaulted historical monumental masonry structures in Pakistan.

2 MATERIALS AND METHODS

A comprehensive methodology has been formulated in the Fig.1 which is formulated based on existing research literature[5, 6] related to historical building damage assessments.

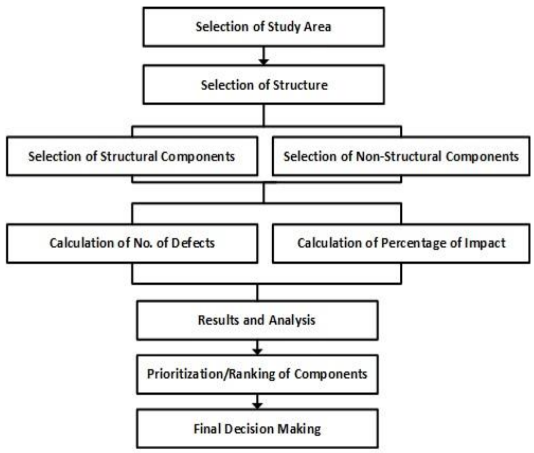


Figure 43. Framework for Research

2.1 *Study Area*

Shah Ali Akbar was a descendant of Hazrat Shah Shams-ud-Din Sabzwari and 18th in line as one of his great-grandsons whose disciples and descendants inhabited the Suraj Miani village. Suraj Miani is situated to the northwest of Multan and it became quite well known during the Durrani period due to its trade with Kabul. So strong was the relationship between Suraj Miani and Kabul that, the houses of the village imitated the style of Afghani residences. Consequently, the village was often referred to as a "Kabuli Mohallah", (Mohallah of Kabul, Multan Gazetteer, 1926). However, there seems to be some Arab influence on the village as well. A local historian has recorded that the original name of Suraj Miani, "Sura Miani", was derived from Al-Mansura—the name of an Arab cantonment during the Abbasi period. There were once several palaces and gardens in the vicinity which today, have been overrun by the urban sprawl of Multan [7].

Figure 44: Location Map of Tomb of Ali Shah Akbar

The Shrine is situated adjacent to the graveyard of Suraj Miani, north of the tomb of the Saint's mother as shown in Fig.2. It is surrounded by residences in the north and west and by the unplanned graveyard on the other sides. The site is accessible through a metaled road from the city. It is believed that Shah Ali Akbar's Shrine was built by master builders hired from Lahore, Ahmed Nabi Khan mentions their names as Ibrahim and Rajab, sons of Musa of Lahore. The builders were trained in the traditions of the early Mughal style of architecture and a unique feast of fresco ornamentations is seen on the Shrine which was unknown to the local artists.

Although this shrine is a smaller version of Shah Rukn-e-Alam's shrine, it is richer in faience embellishment and tile inscriptions as shown in Fig.3. It has an octagonal plan, three stories tall and tapering angle buttresses crowned by turrets similar to the Shrine of Shah Rukn-e--Alam. The entire structure is almost 85 feet in height with an external finish of glazed geometric patterned tiles. These are still intact and reflect the development of the Multani style of the blue tile set in brick masonry. The walls have horizontal wooden beams laid within the masonry courses and are decorated with brick designs and tile work. The openings have wooden grills, some of which have been damaged in the second storey and are now blocked by brick masonry. There are arches one above the other with openings set with wooden fretwork screens in the upper two levels. There is a staircase created within the thickness of the wall just adjacent to the entrance that provides access to the roof of the second storey through one of the windows. The floor of the entrance is finished in large square tiles with a glazed design whereas the rest of the floor inside the shrine is finished with bricks on the edge. The external six feet high platform, upon which the structure rests, has recently been plastered with cement. The front solid wood door is painted green. The interior is richly embellished with original specimens of *naqashi* in *floral* and *geometric* patterns in horizontal and vertical panels, following the structural elements and recesses in the walls. Some of the rarest examples are arabesque designs in relief which can be seen on the interior walls. However, all these specimens currently are in a precarious state. The interior of the monument has been considerably damaged by the smoke of the candles and mustard oil lamps that are lit by the pilgrims visiting the shrine particularly the *naqashi work* and lime plaster. Little of the original decoration survives in presentable condition. Externally, decay has set in at several places including walls, corner buttresses, grills, and panels of inscriptions due to rising dampness and weathering.

Figure 45: Mausoleum of Shah Ali Akbar-Historical shrine of Multan, Pakistan.

2.2 Research Methodology

The first stage of the safety evaluation process is to collect qualitative data by examining the existing status of the building. The qualitative data involves the damage and physical condition of the structure, each structural component, and location of the structure, seismic region, etc. Such information can be collected through visual inspection and literature [8]. The current study area lies in the low seismic zone of Pakistan the zone name 2A (0.8-1.6 m/ sq. sec) has very low hazard probability of earthquakes according to building code of Pakistan [9]

The inspector relates each new case with cases during the assessment of the structure that he/she has seen before and individually makes his / her decision. Due to this fact, inspection depends not only on the current state of the structure but also on the experiences and expertise of the inspector. Thus, to prevent or mitigate this problem, the suggested approach is carried out via the computer database system based on the "the inspection form," which involves a questionnaire with choices. The checklist of damages is also prepared for inspections in which types of damage are described. Such practice makes the method rational and quite common for all surveyed structures. There are a few works in safety assessment and damage prediction on vernacular masonry structures with basic geometry in earthquake zones. After any natural disaster, there are checklists are available for assessing the damage level of existing concrete structures and vernacular masonry buildings such as FEMA (Federal Emergency Management Agency, part of the U.S. Department of Homeland Security). However, the pre-hazard evaluation of historical buildings is rare. It is very necessary to recognize the potential damages of seismic in damage-prone areas for mitigation strategies and minimizing the effect of the disaster to maintain cultural heritage [6]. Thus, previous research studies show, there is no standard and general approach is available for safety and damage assessment of historical structures. There are different methods are in practice for protection and conservation of heritage based on culture, structural typology, and economy of the country. Visual inspection is the first phase of the damage assessment using checklists, questionnaire forms, hazard atlases, etc. It is clear that identifying the structural components with complex shapes and examine the structure as a whole during the assessment process is very crucial but is still a challenge [10]. Due to this reason, only a few specialists are available in this area, as there are many historical buildings present in the world. Therefore, it is recommending that to fill the inspections forms or checklists with the help of non-experts who are willing to survey historical buildings i.e. architectural students. Hence, the specialists will save time for comprehensive inspections that can be worked out for a small number of buildings. So, the Steps to be followed will be as:

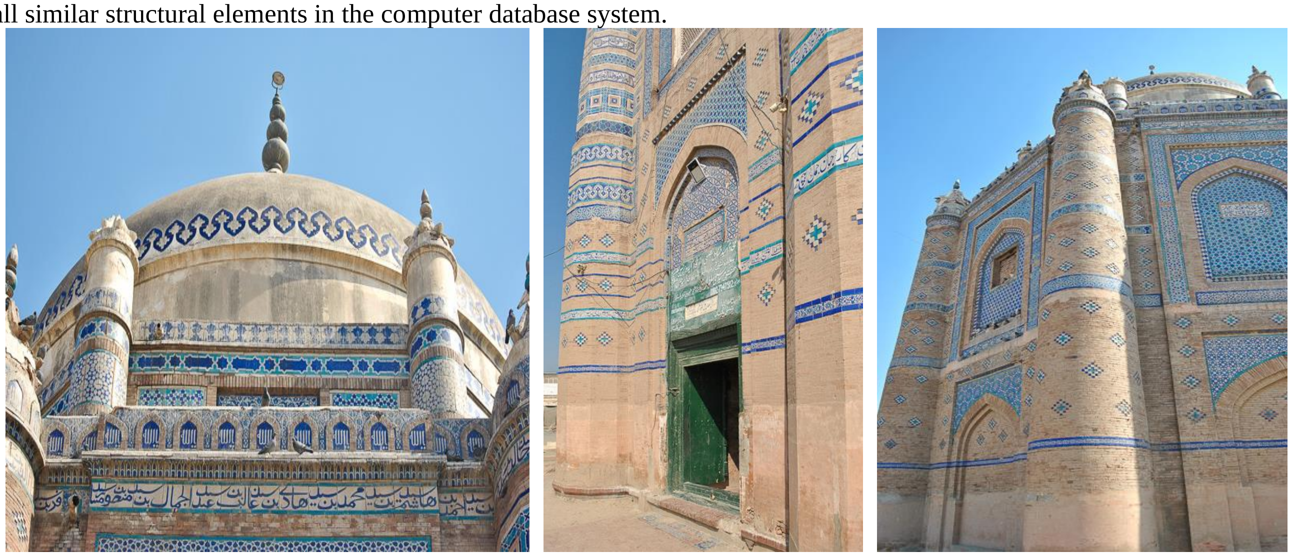
Step. 1: Selection of Structural Component i.e. Walls, Boundary Walls, Roof (Dome/Flat), Arches, Beams, Turrets, Domelets /Kiosks, Floor, Lintel, Pillars, Stairs etc. and Selection of Non-Structural Component i.e. Doors, Windows, Ventilators, Drains, Pigeon Holes etc.

Step. 2: Calculation of number of cracks on each structural and non-structural component. Further, calculation of percentage impact of each components with reference to damage contribution.

Step. 3: Evaluation of Damage Value of each components to set the ranking and prioritization for repair, rehabilitation and conservation.

2.3 Representation of Structural Element.

The computer database program analyzes the inspection data in the proposed system. Therefore, it is important to identify each structural element of the inspected building as well as a general method in computerized data properly using Excel analyzing the existing structure component-wise [11]. Also, checklist and questionnaire forms should be used and organize properly for inspection in a computer database. It is a hard job to examine the structure as well as to make interrelation of all similar structural elements in the computer database system.



a. Dome b. Front c. Columns

Figure 46: Example of Analyzing Existing Structure Component Wise

During the inspection, each structural element is therefore inspected to characterize its real geometry in the form of the datasheet. The structure is divided into components before inspection of the existing structure by which each structural feature can be defined by its actual geometry shapes such as circular, semi-circular, curvilinear, or irregular and its location i.e., orthogonal, or non-orthogonal or octagonal. It is not necessary to be precise in drawing applications while giving the axes and drawing every axis through the center of the component. The focus is to straightforwardly identify all structural components and using the minimum axis lines as much as possible. The way of giving an axial method to historic buildings as an example is displayed in Fig.3.

2.4 The development of the inspection form.

The inspection form has been created by site visits and visual inspection of the Historical shrines in Multan. The inspection form is changed systematically based on experiences and feedback. The data is collected by reviewing the inspection form involving structural typology, topography, visual damage of material degradation, defects, human-made damage, etc. and structural element dimensions.MS Office-Excel software is used to create the inspection form and contains seven key sections as given below.

A-General details,

B-Physical data,

C-Structural elements of dimensions,

D-Images of the building,

E- Damage and the current condition of the facades,

F- Surveyed information of floor,

G- The layout of the interior spaces and damage and the existing condition of the structural elements within.

The inspection tasks are divided into two key sections as a measurement of the dimensions and damage state of inspected structural elements based on the test user's feedback. The first task is to measure all structural elements and to fill in the relevant part of the inspection form by using the code of the element for each inspected structural element. In inspection form, part C is the measuring part divided into external and internal structural elements such as interior and exteriors walls, pillars/columns, and arches/lintels. The first step of inspection will be completed after measuring of all structural elements. Also, the layout of the structure and damage survey are classified as exterior and interior inspection.

3 ANALYSIS OF DATA

In this method, data is collected after selecting shrine, data is analyzed after counting the structural, and non-structural deflects of the shrine. Then, deflects of these components were computed in percentages. There are different criteria for the evaluation of damage by using this method.

3.1 Analysis of Structural Components

In this research, the structural elements such as walls, boundary walls, roof, arches, columns, dome lets/ Kiosks, walls, lintels, staircases, and pillars are observed for damage assessment. On the other hand, non- structural components include doors, windows, ventilators, drains, and pigeonholes. The structural and non-structural components of the shrine were examined, and data was collected by visual inspection. Then, obtained data of each storey structure are presented in table 1. However, example calculation mechanism can be observed as follows:

Component.1: Walls

Total Number of Cracks Observed in Walls=13

Total Number of Cracks Observed on All Structural Components=52

Percentage Share of Cracks of Walls=13/52*100=25%

Detail calculation has been presented in table.1 following the same pattern.

Table 28-Structural deflects of Hazrat Ali Akbar shrine

Defects in Structural Components of the Shrine					
Sr.#	**Shrine**	**Components**	**No. of Defects**	**%age of defects**	**Rank**
1.	Hazrat Ali Akbar (Shrine Age:431 Years)	Walls	13	25%	1
		Boundary wall	1	1.90%	8
		Roof	10	19.20%	2
		Arches	7	13.40%	3
		Beams	0	0%	9
		Turrets	2	3.80%	7
		Domelets/Kiosks	3	5.70%	6
		Floor	7	13.40%	3
		Lintel	5	9.60%	4
		Pillars	0	0%	9
		Stairs	4	7.70%	5
		Total	52	100	

Among, all listed structural components of the shrine in the table, walls have most defected around 25% which is the highest proportion of defection in contrast to other structural components of the shrine. Correspondingly, the roof has the second-highest proportion equal to 19%.

3.2 Analysis of Non-Structural Components

Non-structural components i.e. Doors, Windows, Ventilators, Drains, and Pigeonholes etc. of the shrine further demonstrate the imperfections of the shrine in table 2. Among, all non-structural components, doors and windows of shrine demonstrate major proportion disorder as associated with other components. Following the similar pattern of calculation as explained in section 3.1, percentage weight of defects has been calculated. Further ranking will also help to prioritize the damage level of the components.

Table 29-Non-Structural deflects of Hazrat Ali Akbar shrine

Defects in Non-Structural Components of the Shrine					
Sr.#	**Shrine**	**Components**	**No. of Defects**	**%age of defects**	**Rank**
1.	Hazrat Ali Akbar (Shrine Age:431 Years)	Doors	4	36.4 %	1
		Windows	3	27.3 %	2
		Ventilators	2	18.2 %	3
		Drains	2	18.2 %	4
		Pigeon Holes	0	0%	5
		Total	11	100	

4 CONCLUSIONS

The damage assessment before the hazard is very important in determining the potential threat of the historic masonry structures, especially in seismic areas. The Classification of damage levels helps to mitigate, preserve, and conserve the cultural and heritage building before the hazard. It also gives the ability to guide specialists in the most critical buildings and save time for intensive research. Damage evaluation is a systemic process and requires teamwork. Since there are few experts in this area, who can conduct extensive research whereas the massive historical buildings exist around the globe. Therefore, the participation of non-experts plays a significant role in developing and improve the first phase of damage assessments. Also, comprehensive procedures for damage assessment could be extended and restricted to the most important buildings. In this study, the proposed method adopted to assess the existing condition of the historical masonry monuments through visual inspections, so that necessary steps taken for conservation and protection of historical buildings before any natural hazards. The outcomes results of this study elaborate on the present condition of structural & non-structural components of the shrine that involve numerous components of each structure. Doors & windows type of non-structural components indicate a high proportion of defects equal to 36% and 27 % respectively. Instead, a total of 11 structural components of a shrine out of which 7 components having less than 10% defects proportion of the whole shrine. The remaining 4 components have greater than 10% defects proportion that designates the evidence of improper maintenance and negligence of higher authorities of the shrine. Ranking procedure will also help to take decision about financial and technical prioritization for decision making. Due to which both type defects proportion of shrine further increase in future that damage this cultural and heritage monument. Therefore, the inspected buildings are monitor regularly by conducting the visual inspection that gives direction towards depth assessment of high-damage buildings by specialists.

REFERENCES

[1] B. Feilden, Conservation of historic buildings. Routledge, 2007.

[2] J. Gonçalves, R. Mateus, J. Silvestre, and G. Vasconcelos, "Survey to architects: challenges to inspection and diagnosis in historical residential buildings," in *3rd International Conference on Preservation, Maintenance and Rehabilitation of Historical Buildings and Structures (REHAB 2017)*, 2017, pp. 3-10: Green Lines Institute for Sustainable Development.

[3] L. Binda and A. Saisi, "Research on historic structures in seismic areas in Italy," *Progress in Structural Engineering and Materials,* vol. 7, no. 2, pp. 71-85, 2005.

[4] Icomos, "Recommendations for the analysis, conservation and structural restoration of architectural heritage," ed: International Scientific Committee for Analysis and Restoration of …, 2001.

[5] M. Vatan and G. Arun, "A method for assessing the risk level of monumental historical structures by visual inspections," in *Proceedings of the 14th European conference on earthquake engineering (14ECEE). Ohrid, Macedonia*, 2010, vol. 30.

[6] W.-K. Chong and S.-P. Low, "Latent building defects: causes and design strategies to prevent them," *Journal of Performance of Constructed Facilities,* vol. 20, no. 3, pp. 213-221, 2006.

[7] A. N. Khan, *Multan: history and architecture*. Institute of Islamic History, Culture & Civilization, Islamic University, 1983.

[8] D. D'ayala and E. Speranza, "An integrated procedure for the assessment of seismic vulnerability of historic buildings," *disp,* vol. 3, no. 1, pp. 3-3, 2002.

[9] S. BCP, "Building Codes of Pakistan Seismic Provisions Government of Islamic republic of Pakistan Ministry of Housing and Works," ed: Islamabad, 2007.

[10] R. Mansor, M. A. O. Mydin, M. Ismail, and W. M. W. Harun, "Categorization of General Problems and Defects in Historical Building," 2012.

[11] M. Vatan and G. Arun, "Risk level assessment of monumental historical structures by visual inspection," in *Building materials and building technology to preserve the built heritage" 1st WTA-International PhD Symposium*, 2009, pp. 159-172.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

SUSTAINABLE DESIGN OF BUILDINGS THROUGH BIM: A COMPREHENSIVE REVIEW

[a,*]Abrar Ahmad, [b]Umar farooq, [a,*]Sardar Kashif Ur Rehman, [a] Abdul Waheed, [a] Akhtar Zeb, [a]Abdur Rasheed
a: Civil Engineering Department, COMSATS University Islamabad Abbottabad Campus.
b: Department of Construction Engineering and management, Military College of Engineering, NUST, Risalpur, Pakistan
*: Corresponding Authors. abrarahmad9239@gmail.com (A.A) ; skashif@cuiatd.edu.pk (S.K.U.R)

Abstract- Building Information Modeling (BIM) is an effective and emerging approach for managing the complex construction projects. BIM has been successfully applied in construction industry. However, several compatibility issues were recorded. This article provides an overview of the literature on sustainable digital building models. Moreover, it covers cost estimation, energy savings, energy analysis, carbon calculation and waste management in the buildings. Furthermore, this study suggests that these parameters should be considered at an early stage of project. In practice, this type of management is usually done at later stage in the design process, which leads to the re-design of complete project. In addition to this, it also provides information on the various software tools that can lead to the selection of efficient structure. Autodesk Review, Dynamo Factory and HBERT Recovery are the different softwares selected. Future aspirations are also offered for implementation.

Keywords- BIM, cost estimation, energy efficiency, sustainable buildings.

List of Abbreviations: Building Information Modeling (BIM); Computer Aided Design (CAD); Mechanical electrical plumbing (MEP); Architecture, Engineering, and Construction (AEC); Cost model (CM); Carbon dioxide CO_2; Leadership in Energy and Environmental Design (LEED); Green Building Index (GBI); Energy Efficiency (EE); Indoor Environment Quality (EQ); Materials and Resources (MR); Water Efficiency (WE); Revit Green Project Template (RGPT); International Energy Agency (IEA); Building Energy Modeling (BEM); Agent-Based Modeling (ABM); visual programming language (VPL); industrial information classes (IFC); IDA Indoor Climate and Energy (IDA ICE); Plumbing Engineer (ME); Building Management System (BMS); Facilities Management (FM); Construction and destruction (C&D); Life Cycle Assessment (LCA); Life Cycle Costing (LCC); Incorporated Material Profile and Costing Tool (IMPACT).

1 INTRODUCTION

Normally the building components were drafted by architects, engineers through symbolic language using setsquares, T-squares and pencils. In 1980's, the Architects and engineers shifted towards Computer Aided Design (CAD) but the fundamental manual method of symbolic expression remains the same. The BIM innovation is another emerging method of managing complex development projects. It predominantly concentrates on the flowing of tasks information which are fed into the advanced model. Thus, it is the technique through which the digital model of the structure is developed which is rich in information including MEP (mechanical electrical plumbing), architectural and structural models. The digital model starts initially from 2D drawings which is converted into 3D [1] model and then, there is 4D model related to project scheduling, 5D related to cost estimation, 6D sustainability, 7D related to safety and 8D related to Assets management. As the BIM covering broad areas of technology practicing in Architecture, Engineering, and Construction (AEC) industry. But the primary need is to develop strong coordination between the academia (who continuously develops new research techniques) and the AEC industry to adopt this emerging technology in real engineering practice. Hence, In this research we will cover the cost estimation, embodied carbon calculation, waste management, and energy analysis though BIM approach and will be shared with AEC industry for awareness purposes.

2 RESEARCH SIGNIFICANCE

This research will cover the cost estimation, energy analysis, carbon calculations, and waste management through BIM technology. The related areas will then debate the implementation issued in the industrial zones and try to highlight the reasons which hinders the BIM technology in the construction zones. By stating and clearing the issues in real implementations, will minimize the cost of overall projects in terms of management and coordination. Also, providing best decision making tools in real scenarios and good approach to environment friendly constructions.

3 COST ESTIMATION

Cost estimation is a strenuous and tiring process, which mainly include changes and reworks calculations [1]. It happens in a huge number of projects due to unforeseen and unexpected scenarios occurring in the construction field. BIM can assist effectively in reducing the reworks to establish more reliable estimate as compared to manual estimates. Through BIM enabled model, it is possible to simulate different scenarios for the clients keeping financial constraint in mind. Table 1 shows the current utilization of BIM in construction industries for various activities. About 75% is using BIM for visualization and 55% for estimating purposes. The cost manager should be well-aware to utilize the BIM model for the project financial management. The traditional way of estimating involves meetings, work plan, schedule, estimate preparation, documentation, reviews and adjustments and then feedback upon completion. However, BIM estimation follows the same footsteps, but the advancement brought the errors and uncertainties to minimum level by extracting information from 3D rather than 2D model.

Table 30 : Application of BIM in construction industry based on activities [2]

Activities	Percentage
Scheduling	42%
Marketing	45%
Visualization	75%
Estimating	55%

1.1 BIM Adaptation for cost estimation

BIM adoption has been tremendously increased in many countries like Australia, USA, Europe and Middle East. Different organizations like International Alliance for interoperability, CRC-IC, ANZRS, PBS also played a vital role in promoting this technology. In USA BIM implementation grown up from 17% to 71% from 2007-2012 [3]. Similarly, the Building Smart Australia conducted a survey, which reveals the highest adoption rate [4]. The overview provided by National Building predicts that 13% of private organizations utilize BIM in their projects. As BIM is inclined towards development industry, and numerous nations settled on choices to require BIM in broad daylight contracts. One of its usage is the utilization of BIM for projects cost estimation. Various researchers conducted a survey from construction sector specialists and firms to decide the degree to which assessing forms were automated with the help of BIM model. Questionnaire was designed to extract information about how BIM was utilized inside their association and how it was utilized in the different projects engaged with cost estimation. Information presented in Table 1 was obtained from the survey and highlights the applications and utilization of BIM in various stages of the project within construction industry [6]

1.2 Implementation issues

Table 2 shows the results obtained from the survey conducted by Farooq., et al. [2]. There are likewise some usage issues in BIM for the cost estimation but when once implemented, will decrease the estimation time from weeks to certain minutes. The issues in the BIM software is that of interoperability and reliability of data [4]. Because of the absence of consistency, the data during transferring among various software get missing. It is intended to create technique and devices to meet the necessity of small scope industry procedures for cost estimation through BIM. For example, cost evaluating and booking must be reengineered thinking about the new innovation. BIM has just been received by a few contractual workers in the US and is rapidly picking up familiarity inside the construction sector. The future goal for Building

Information Modeling is for general laborers to have the alternative to opt out a quantity takeoff in a matter of seconds. BIM isn't improving nature of estimations or decreasing the time required for cost estimation for contractors [6]. This could be the eventual outcome for large general contractor having separate divisions for surveying and BIM, having negotiable contracts, gives favorable results for contractors most of the time. This prevents the feasibility of detailed BIM model. There need to be an upgrade in BIM modeling before going into legal binding with contractors. Organizers and design engineers need to make BIM models with enough information so statements may be made without the contractors, redrawing entire models without any preparation. [6] Detailed and exact drafts of competition are required to effective BIM execution. The investigation has been led for the transportation cost estimation in Czech Republic. This shows that it must be guaranteed by determinations in contract, the extent that data model and Cost model (CM) are concerned. The determinations required are information arrangement and Execution plan of building data demonstrating it to be remembered for contract. [5]. The paper here is for various cases when all is said to be done, so the outcomes are applicable for most of the individual framework of cost estimation throughout the world. The presented solutions are then compared to show their advantages and disadvantages. The various issues it face are

a. Sometimes drawings and specification are in conflict with each other.
b. Misunderstanding of drawing by designer or surveyor.
c. It is time consuming process.
d. When drawings are in large amount it becomes very difficult.
e. Chances of human error.

Table 31: Different implementation barriers [2]

Barriers	Rating
Absence of government guideline about BIM	78%
Absence of classes on new advances like BIM by firms	77%
BIM adjustment requires authoritative rebuild	72%
Absence of BIM experts	70%
Absence of competency to organize projects though BIM	64%
Poor communication in organization	60%

4 GREEN BUILDING THROUGH BIM

Currently the world has a lot of challenges due to environmental changes and global warming. From recent research we came to know that some industries have an immense role in creating green buildings, particularly the construction industry. The Green BIM projects have improved the sustainability by developing sustainable design by using natural resources and prevail environmental quality by reducing toxic waste[6]. From recent studies it was observed that applications of BIM not only reduce CO_2 emissions but also makes environment pleasant by reducing use of fossil fuels[7]. The construction industry realizes to produce the green building we should use strategies to reduce the CO_2 emission. The green building has less effects on environment as compared to the conventional building throughout the building life cycle. Due to this the green building is used as innovative operation for Energy Efficient Environment.

1.3 Challenges in adoption of BIM for Green building

From recent studies we know that the unsuitable materials used in building damaged the environment as well as the health of human. So, the question arises is that how to resolve these issues. Some engineers have proposed that we can easily resolve these issues by preferring green and sustainable buildings. We know that the main goal of the green building is to move from harmful to harmless materials used in buildings. This results in decrease of energy usage, CO_2 emission, water resources etc. We know that the green buildings can reduce the harmful effects on the environment.[8] Government of

Malaysia pronounces various sorts of incentives for construction improvement in Malaysia. The incentive is grouped into three; financial incentive, fiscal incentive and structural incentive. Due to the case financial incentive building developers are attracted to adopt a green building and they submit their documents for new projects. Structural incentives are much more important because we can use such a material that can be recycled and reused.[8] The sustainable green building enhance the natural light, rain water system and much more. The green building have a lot of benefits to the constructors and as well as the purchasers but we should prefer the standards like LEED which can enhance the environment.[6] The capacity, supportability and combination of green structure evaluation with BIM is the principle expectation to be finished. "Green BIM Triangle" is scientific categorization which gives a systematic way to deal with the current range of information on green BIM.[7] The GBI introduced environmental friendly features like EE, MR, WE, EQ, etc. RGPT is produced to help the user of BIM in documentation & assessment of Green buildings. These tools help in saving time.[7] In India the number of population is expected to increase massively, focused by population development. Due to increase in population, increase in construction is also expected. So in the recent year advancements in the building construction is important in survey analysis headed by the professionals who have great contribution in green construction. The green building helps to incorporate expenses, reduce the energy consumption and beneficial well-being. In addition it is now necessary to achieve more green building construction through the green and sustainable building polices [9]

5 ENERGY ANALYSIS THROUGH BIM

In last decade energy consumption is increasing rapidly by the rise of population. The proper energy consumption can be achieved by proper design and operation. One of the effective ways to achieve this is by BEM. Through BIM model which is rich in data and digital representation of facilities for the energy efficient building using BIM based BEM model. In the structure planning process Energy reproduction devices are ordinarily utilized daily. They permit originators to anticipate the energy required to give interior natural relief, while conveying an ideal degree of vital productivity. In most of the daily life structures, which are maintainable structures, it is important for engineers and experts to work even more carefully in a multi-disciplinary group with a common objective of the energy and natural environmental impacts of new structures. The International Energy Agency (IEA) has recognized a coordinated structure process (IDP), conveyed through a multi-disciplinary plan group is essential for effectively managing structures. In the construction industry the necessary degree of multi-disciplinary joint effort in building configuration isn't ordinary. The construction is directly related to an unnatural weather change, the construction industry is starting to concentrate more on energy utilization of the structure and to address energy efficient structure.[10].

1.4 Application of BIM for energy analysis

Recently numerous devices are produced to demonstrate building energy (BEM) or building energy utilization by the merging through Agent-Based Modeling (ABM). Ordered trade of information from BIM to BEM. The BIM information sent out as contribution to Energy Plus. Two three-dimensional processing models, BIM and BEM are leading in divided style. Making a BIM model, the parametric and social information trade among BIM and BEM is created in operator-based model. A portion of the model examine in paper are effort at reproducing the effect that inhabitant on building energy utilization. At long last set of models archived after energy examination result that up to 11% energy consumed by utilizing BIM for BEM. During surveying of large scale systems conducted on the active and differing energy by utilizing BIM, BEM and ABM. Results of surveys introduced were not reliable, made in BIM model utilized the visual programming language (VPL) to systematize the parametric information trade with BEM and ABM. Construct an ABM which interact with environment and made decisions based on visual comfort level. Documentation of the behavioral decision and export of BIM model and energy consumption generated. Validated the proposed BIM, BEM and ABM framework by comparing with results.[11] methodology workflow is summarized in following four points:

1. Create architectural model or 3D model in Revit.
2. In second step import the industrial information classes (IFC) data into IDA Indoor Climate and Energy (IDA ICE) energy simulation tool.
3. Energy simulation setup described in detail.
4. Merge IDA-ICE results within IFC file.

The construction industry consumes energy and natural resources and is commonly known as "the industry of the 40%", since buildings produce nearly 40% of overall CO_2 emissions, 40% of overall waste generation and consumes 40% of overall natural resources over their entire life spans. The world witness increases in awareness with regards to enhanced energy efficiency in construction. Figure 1 shows the impact of construction industry on the economic activities and resources utilization. BIM has been proposed as an innovative approach with multidisciplinary tools that can effectively evaluate energy performance in buildings by harmonizing information of building material and facilitating the calculation of their environmental impacts. In the last decade, the energy consumption of buildings has been intensely increasing, driven by the rising population, growing economy and higher demand on life quality. Nevertheless, significant energy savings can be achieved, if buildings are properly designed, constructed and operated.[12]

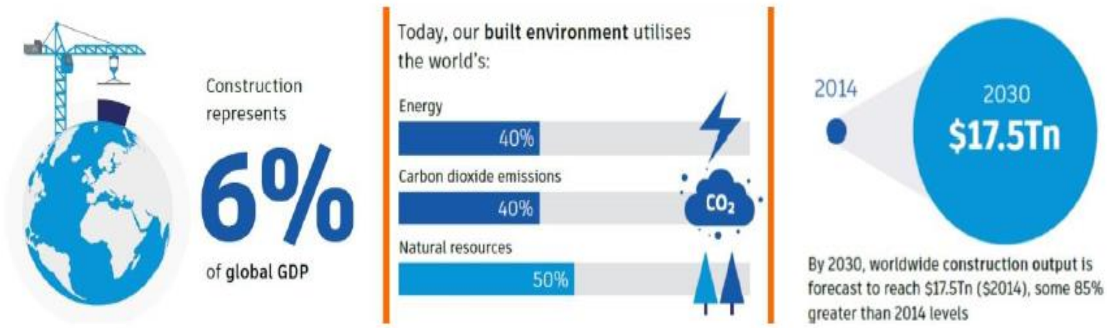


Figure 47:Impacts of the construction industry on economic activities and resource utilization [12]

1.5 Implementation issues

Despite the various possible advantages of using BIM, there are some issues which are related to real life scenarios to implement. BIM adoption is a progressive task, and is a difficult assignment. The utilization of BIM also brought some hazards and risks including expert hazard, the administrator's chance, natural hazard, money related hazard and legitimate hazard. One of the fundamental difficulties associated with BIM movement is the licensed innovation and digital security of BIM apparatuses results. As data sharing makes sensitive information open to all staff, digital security is a worry because of the chance of online unapproved access and copyright violation. Also, the improvement of far reaching and clear re-use and response approaches for BIM models either by a similar group for various purposes or by others is a difficult undertaking. Lawful concerns likewise exist, issue is with responsibility to ensure the privacy of data as the model is rich with data of all disciplines. Moreover, joint initiation of various BIM model, engineers confuses joint and separate obligation for any mistakes made during the undertaking lifecycle. The exactness of information of the BIM model involves significant risks and the duty regarding this accuracy must be defended by responsible authorities just as constrained guarantees from the planners[13]. The absence of categorized responsibility is who claims and regularize the execution information, was told by every interviewee. Conduct difficulties stay a critical obstruction to innovation and procedure comment by the interviewees as hesitance to take on extra duties. A past encounter of the ME incorporated an account where after being asked where the BMS was, the FM reacted, "what's that?" as it had been covered up in a cabinet while the structure was being controlled physically.[14] Absence of instruction and Lack of training is one of the most testing hindrances for BIM selection in construction industry. The absence of instruction on BIM reminders is lacking of abilities, and demonstrable skill in the genuine work environment. There is a deficiency of tertiary training that helps in conveying BIM information through talk or lab mix, familiarizing the aptitudes with model for assessing and getting drawings. Restricted training programs were familiar with tertiary instruction understudies on BIM innovation. The number of educational organizations bringing BIM into their educational plan. Difficulties exist when there are challenges in preparing staff in region of information taking care of. The representatives of associations may require finishing certain confirmation to have the option to take part in the new authoritative procedure. Troubles emerge in preparing individuals in BIM and conquering protection from change and the weaknesses identifying with learning new programming and rethinking work process forms.[15]

6 APPLICATION OF BIM FOR WASTE MANAGEMENT

The waste generated on construction site is mainly due to rework, insufficient coordination and collaboration. Figure 2 presents the salvage performance of building over the period of 60 years. 4D BIM develops construction planning, scheduling and on-site management of waste as well as enhance communication and information flow. BIM helps undertaking members improve the measures of plan development and destruction stages. Furthermore, limiting Construction and destruction (C&D) waste is commonly a mix of surplus materials emerging from development and devastation exercises including land diggings, street fixes, remodel and pulverization [16] . Renovating present buildings and recycling remaining construction materials provide the true solution to lessen waste and minimize impacts on the environment. To control C&D waste management practices, a specific set of frameworks is required that should include the better practice for managing waste and achieve minimum waste strategy [17]. There is a collective need to lessen construction waste as well as encourage further sustainable construction. Incorporated Material Profile and Costing Tool (IMPACT) is a database with comprehensive point of coordinating Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and BIM [17]. It is anticipated that 4D planning, diversion and origination can propel the aggregate improvement of development natural administration plans and they're on location observing.

This research is based on the facts and results from the prior construction projects and areas that generates the maximum amount of waste in a construction project. BIM being the latest addition to manage waste in the industry, the idea is to integrate the proposed framework into BIM as described in the introduction. The information gathered from numerous urban areas demonstrates that enough development and destruction waste is delivered throughout Construction phases in various segments of the world which vary from 18 kg for each capita/year to 842 kg for every capita/year [18]. Moreover, the Environmental effects of materials changed into waste is evaluated in an incorporated situation by developing an enhancement inside BIM device (LCA), which registers waste shaped in each progression of structures lifetime

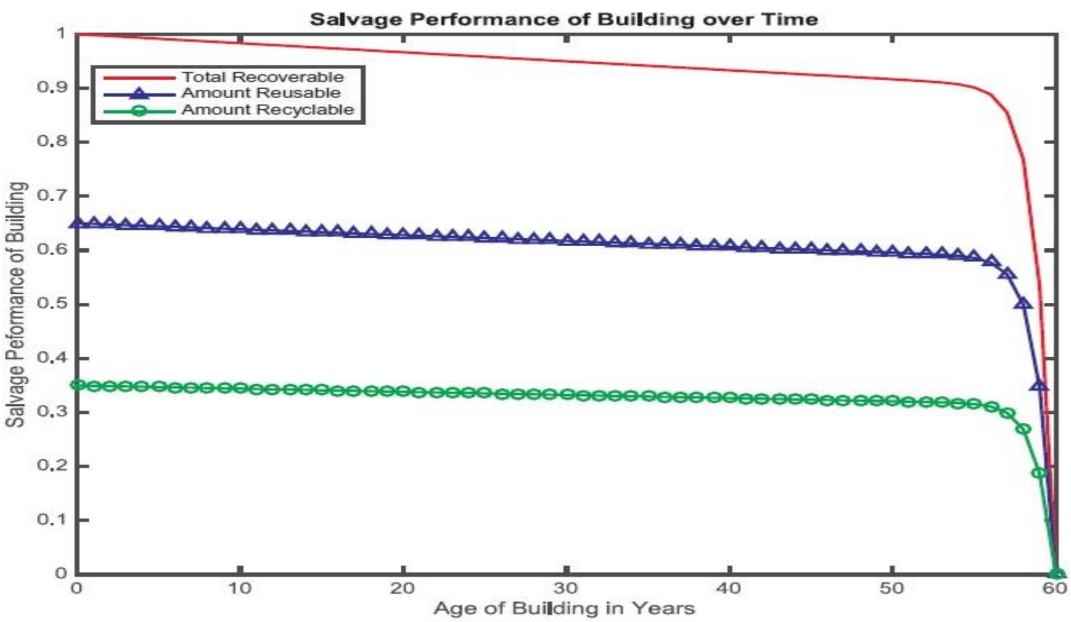


Figure 48: Salvage performance of building [15]

1.6 Tools usage and selection survey for the different analysis of digital model.

Various software tools are used to prepare digital models. This section provides a brief overview of previous articles. The general findings of the literature review are shown in Table 3. It contains data on the use of tools for various activities carried out in BIM.

Table 32: Digital tools normally used in BIM enabled projects

S No	ACTIVITY	TOOL NAME	REMARKS
1	Quantity takeoff	Autodesk Revit	Basic detailed schedules are prepared

2	Cost management and optimization	Autodesk Revit with dynamo refinery	Extension of Autodesk Revit 2018
3	Surface area to volume ratio optimization	Generative design tool with dynamo refinery in Revit	Extension of Autodesk Revit 2018
4	Equipment arrangement and natural light optimization inside building	Dynamo Refinery Autodesk Revit 2018	Extension of Autodesk Revit 2018
5	Carbon calculation for green building	Hubert in Autodesk Revit 2018 and green building studio	Extension of Autodesk Revit 2018 and cloud storage.
6	Energy Analysis	Autodesk Revit	Extension of Autodesk Revit 2017
7	Heating and Cooling load Analysis	Autodesk Revit with zoning	Extension of Autodesk Revit 2017

7 PRACTICAL IMPLEMENTATION IN INDUSTRY

The current research highlighted the problems in industry and reviewed the four aspects of BIM technology. With the practical implementation of this technology, the construction industry can easily overcome all the problems related to cost and time overruns, minimizes reworks and managing a project effectively and efficiently.

Similarly we know that environment care is one of the challenging task in the modern world and the concept of green building is one of the modern option available which is possible through BIM enabled model in the terms of operation and embodied carbon calculations.

8 CONCLUSION

BIM technology is tremendously increasing in the AEC industry. Based on above observations following findings are drawn:

- Government should focus and support the BIM technology in their projects to achieve sustainability.
- Due to the lack of professionals, its developments are hindering so the universities should offer courses regarding BIM.
- The industries need to focus on this new technology. As it is difficult to implement in start but once implemented, it will reduce the fatigue from month to weeks and days.
- As some features are designed especially for the collaboration so, BIM can be proved very effective in project management.

ACKNOWLEDGMENT

The Authors would like to thank COMSATS University Islamabad, Abbottabad Campus for providing the research facility and funding. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] N. A. A. Ismail, N. H. Idris, H. Ramli, S. R. Sahamir, and R. R. R. M. Rooshdi, "Sustainable BIM-Based Cost Estimating for Quantity Surveyors," *Chemical Engineering Transactions*, vol. 63, pp. 235-240, 2018.

[2] U. Farooq., S. K. U. Rehman., R. Shoaib., N. Khan., and A. Haider., "Adoption and Awareness of Building Information Modelling (BIM) in Pakistan," in *1st Conference on Sustainability in Civil Engineering, August 01, 2019.* , Capital University of Science and Technology, Islamabad, Pakistan., 2019.
[3] P. Smith, "BIM & the 5D project cost manager," *Procedia-Social and Behavioral Sciences*, vol. 119, pp. 475-484, 2014.
[4] F. K. Cheung, J. Rihan, J. Tah, D. Duce, and E. Kurul, "Early stage multi-level cost estimation for schematic BIM models," *Automation in Construction*, vol. 27, pp. 67-77, 2012.
[5] A. Sattineni and R. H. Bradford, "Estimating with BIM: A survey of US construction companies," *Proceedings of the 28th ISARC, Seoul, Korea*, vol. 564, p. 569, 2011.
[6] B. Neyestani, "A review on sustainable building (Green Building)," *Available at SSRN 2968885*, 2017.
[7] Y. Lu, Z. Wu, R. Chang, and Y. Li, "Building Information Modeling (BIM) for green buildings: A critical review and future directions," *Automation in Construction*, vol. 83, pp. 134-148, 2017.
[8] S. Z. Hashim, I. B. Zakaria, N. Ahzahar, M. F. Yasin, and A. H. Aziz, "Implementation of green building incentives for construction key players in Malaysia," *International Journal of Engineering and Technology (IJET)*, vol. 8, pp. 1039-1044, 2016.
[9] S. Vitásek and P. Matějka, "Utilization of BIM for automation of quantity takeoffs and cost estimation in transport infrastructure construction projects in the Czech Republic," in *IOP Conference Series: Materials Science and Engineering*, 2017, p. 012110.
[10] G. Spiridigliozzi, L. Pompei, C. Cornaro, L. De Santoli, and F. Bisegna, "BIM-BEM support tools for early stages of zero-energy building design," in *IOP Conference Series: Materials Science and Engineering*, 2019, p. 072075.
[11] M. Hajj-Hassan and H. Khoury, "Behavioral and parametric effects on energy consumption through BIM, BEM, and ABM," 2018.
[12] S. Suwal, M. Laukkanen, P. Jäväjä, T. Häkkinen, and S. Kubicki, "BIM and Energy Efficiency training requirement for the construction industry," in *IOP Conference Series: Earth and Environmental Science*, 2019, p. 012037.
[13] A. Ghaffarianhoseini, J. Tookey, A. Ghaffarianhoseini, N. Naismith, S. Azhar, O. Efimova, *et al.*, "Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges," *Renewable and Sustainable Energy Reviews*, vol. 75, pp. 1046-1053, 2017.
[14] T. Gerrish, K. Ruikar, M. Cook, M. Johnson, M. Phillip, and C. Lowry, "BIM application to building energy performance visualisation and management: Challenges and potential," *Energy and Buildings*, vol. 144, pp. 218-228, 2017.
[15] S. Wong and J. Gray, "Barriers to implementing Building Information Modelling (BIM) in the Malaysian construction industry," in *IOP Conference Series: Materials Science and Engineering*, 2019, p. 012002.
[16] Y. Wei, A. Pushkar, and B. Akincia, "Supporting Deconstruction Waste Management through 3D Imaging: A Case Study," in *ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction*, 2019, pp. 438-445.
[17] J. Won and J. C. Cheng, "Identifying potential opportunities of building information modeling for construction and demolition waste management and minimization," *Automation in Construction*, vol. 79, pp. 3-18, 2017.
[18] F. Jalaei, M. Zoghi, and A. Khoshand, "Life cycle environmental impact assessment to manage and optimize construction waste using Building Information Modeling (BIM)," *International Journal of Construction Management*, pp. 1-18, 2019.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

A REVIEW OF VIRTUAL, AUGMENTED AND MIXED REALITY TECHNOLOGIES FOR CONSTRUCTION

[a]Engr. M Abubakar Tariq and [b]Dr. Salman Azhar
a: Department of Civil Engineering, International Islamic University, Islamabad, Pakistan. Email: abubakar.tariq@iiu.edu.pk
b: McWhorter School of Building Science, Auburn University, Auburn, USA, salman@auburn.edu

Abstract- Construction is an important industry which has a potential to uplift the social and economic progress of any country and is directly related to improve the quality of humans' life. Unfortunately, its operations are very complex that hinder its performance to its full potential, thus, very less improvements are made to increase its productivity and efficiency as compared to other industries. Furthermore, it is a slow adopter of new technologies due to associated cost and risk. Recent visual technologies, such as, Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) are developed and being adopted in different trades. With the development of Building Information Modelling, it is possible for the construction industry to employ these technologies. This study is aimed at reviewing the latest developments in VR/AR/MR technologies and presents a fundamental understanding of these technologies. The adoption of these technologies by the construction industry at present is also given. Furthermore, a few practical applications of VR/AR/MR for the industry are outlined. Nonetheless, few research gaps are highlighted that need to be explored by the research community. The VR/AR/MR technologies seem promising to offer benefits to many industries including the construction sector, however, as these technologies are new at present, an in-depth exploration, investigation and analyses are required for a practical and profitable adoption.

Keywords- Augmented Reality, Construction Industry, Mixed Reality, Virtual Reality

1 INTRODUCTION

The construction sector is a significant player in the socio-economic development of a country [1], however, it falls short when it comes to productivity as compared to other industries [2-3]. The construction industry is unique as contrary to other industries due to the following facts: its operations are conducted in natural conditions on site encompassing huge supply chains; it is labor intensive; a considerable number of public and private stakeholders are involved. Furthermore, it does not quickly adopt the latest technologies [4] due to associated cost and risk [5]. However, due to increasing complexity of construction projects and global pressure to adopt sustainable practices, the industry is gradually moving to adopt the latest technologies to realize its full potential.

Building Information Modelling (BIM) is a revolutionary development in the Architecture, Engineering, Construction and Operations (AECO) industries [6]. There are lot of definitions of BIM explaining different significant benefits it provides. In its core, it is a technology-enabled process that enables stakeholders of a project to collaboratively work throughout the lifecycle of a project, such as, planning phase, execution phase, as well as, operations phase of a facility [7]. However, BIM in its standalone form cannot provide an immersive experience of a facility at the design stage, placement of the model on site to be critically analyzed within its surroundings where the facility is going to be constructed, and/or information to a construction worker in real-time while executing the task on site to improve their performance.

Lately new technologies, such as, Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) have emerged. It is pertinent to know that these technologies did not develop specifically for the construction industry, but due to their apparent potential construction researchers and practitioners are exploring the possible benefits they can provide to the industry. As the adoption of BIM is on the rise, it is making the utilization of VR, AR and MR possible for the construction sector [8].

There are numerous studies available that focus on one or two technologies but not all three in one study. Additionally, no clear distinction is being made among these technologies. To address this research gap, this review paper encompasses all three realities (VR/AR/MR) in one study and provides fundamental understanding of these technologies. Furthermore, a differentiation is offered among these technologies for better understanding, which is not widely present in the literature. Thus, the main purpose of this review paper is to identify and outline VR/AR/MR applications for design and construction. This investigation is significant for academicians and practitioners of the construction sector so as to increase their understanding about these new technologies before they can employ these realities in their work. Moreover, this study also outlines the research gaps for possible future research work.

2 RESEARCH METHODOLOGY

Research methodology adopted for this review paper is systematic literature review of VR/AR/MR, their historical development, and adoption in the construction sector. A critical analysis of the published research work is conducted so as to clearly outline what is VR/AR/MR, historical development, functionality and devices required to employ each of these technologies. Moreover, differentiation among these technologies is made to explicitly know the functional boundaries of VR/AR/MR. In addition, their utilization at an appropriate project life cycle is also noted. Furthermore, adoption of these technologies in construction industry with the help of BIM as a back-end support system is outlined. The study also presents a few practical applications for the industry, as well as, research gaps for academia to explore further.

3 RESULTS

This section presents the discussion based on critical analysis of VR, AR, MR, their utilization in the construction industry at present and research gaps that should be investigated for a holistic understanding and subsequent utilization of these technologies.

3.1 Background.

Milgram [9] gave the concept of reality continuum as shown in Figure 1. The two extremes of the continuum separate real world (on the left-hand side of the continuum) and a virtual world (on the right-hand side of the continuum). It means that the real world and the virtual world are two separate entities. In between these two extremes, comes the AR and Augmented Virtuality (AV); both AR and AV fall under the category of MR. An MR is a combination of the real and virtual worlds. The difference between AR and AV is that in the former virtual information is overlaid on to the real world, whereas, in the latter virtual objects are used as a background for the real world. AR gained more recognition and adoption in different sectors, such as, medicine, education, manufacturing and construction as compared to AV, which is just used in the entertainment sector [10].

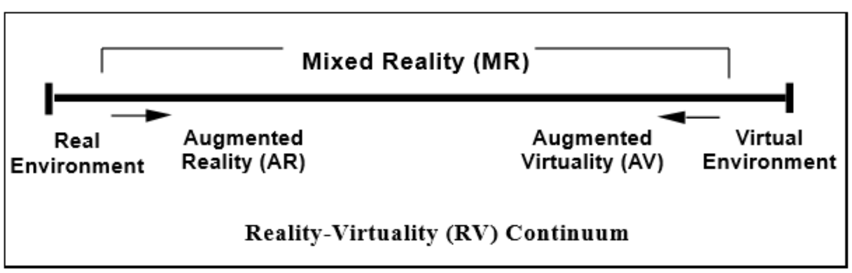


Figure 49: Reality Continuum by Milgram [9]

3.2 Virtual Reality (VR):

The VR as the name suggests, is a virtually created reality as contrary to an actual reality surrounding us [11]. It is created through computers that replace physical reality. These two realities do not overlap with each other, meaning only one reality can only be experienced at a time. The aforementioned explanation is evident from Milgram [9] reality continuum.

A VR is experienced with the help of a virtual reality headset, also known as Head Mounted Display (HMD) device. The HMD is locked on to the head for an immersive 360° experience. The virtual reality created through a computer with the help of HMD displays a 360° field of view within the headset. The formation of a headset, as shown in Table 1, is such that it completely blocks the physical world around the user and the 360° field of view tricks the human senses to believe that the user is a part of the virtually created digital world [11].

The VR can improve the design process of a construction facility by providing an immersive experience at the design phase [13]. The designers can make better design while having an immersive walkthrough before it is finalized and shown to a client. On the other hand, clients and end users can have an immersive visualization [14] to have a better comprehension of the design right at the outset that can support rapid decision making on their part to give a go-ahead to the project. Further, it can improve a customer's satisfaction of the design, thus reduces scope creep and delay in a construction project due to constant change orders from the client. Additionally, the VR is employed for health and safety trainings of workers [14] for a construction site to reduce loss of life and injuries due to risks at construction sites.

3.3 Augmented Reality (AR):

The AR as the name suggests, augments actual reality. It means that AR enhances the physical reality around a user with virtual object(s), thus, supplementing and enhancing actual reality [11]. The user can see the real reality, as well as, superimposed virtual objects at the same time unlike VR, where either the virtual or actual reality can be experienced at a particular point in time [12]. It is also observed from the reality continuum that AR is closer to the actual reality [9].

The AR is usually observed through mobile phones and tablets as shown in Table 1. Numerous AR applications, mostly gaming and entertainment, have been developed and are available in Apple App Store and Android Play Store. Different virtual objects can be overlaid in surrounding and seen through a screen of a gadget. A user cannot interact with those virtual objects in a way to feel it as a real object. It is just a virtual object that can be seen through a screen on to the real environment around a user.

There are different applications, such as, 'Augment' and 'Architecture', through which design model of a construction facility can be overlaid in physical reality through mobile phones and tablets. These applications, for instance, Augment, also works with BIM and the model can be transferred to the app to be shown in AR. It would be a better approach to discuss the design through a 3D BIM based AR during a client meeting rather than a paper based 2D design. Nevertheless, all these applications are new and paid at the moment, thus rigorous scrutiny and adoption is not taken place.

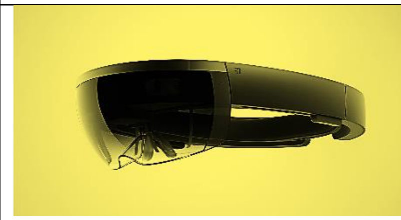
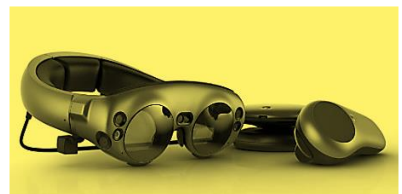
3.4 Mixed Reality (MR):

The MR as the name suggests, is the combination of two realities i.e. real and virtual. According to Cheng *et. al.* [10] MR and AR are confusing and there is no clear differentiation between them; the AR is regarded as a subset of MR and both are considered one and alike at times. Nevertheless, a subtle difference between the MR and AR is based on 'interaction' and 'devices' used to experience these realities.

The MR is experienced through a headset, but contrary to a VR headset, it does not block a user's complete field of view. The headsets, for instance, Microsoft HoloLens and Magic Leap One as shown in Table 1, overlays virtual information on to the screen of the headset in the form of text, diagram or video etc. in real time for the user's support to do a task efficiently, such as, a technician assembling a car engine or construction work assembling pipes [8]. The purpose of MR is to make available the relevant information at the time of performing a task so that it can improve productivity. Nevertheless, MR is a fairly new technology and is still under examination to be employed by different sectors, such as, automotive, remote assistant, engineering and teamwork [15].

For the construction sector MR can be helpful in design creation and on-site client's meeting by placing a 3D holographic 1:1 model on a site. The stakeholders of a project can view, analyse and take decisions about the project using this hologram. Furthermore, the technology can support in efficient working such as assembling on a construction site [8].

Table 33: Devices Required for VR, AR and MR Technologies

VR	**AR**	**MR**
		
Oculus Rift S	Mobile	Microsoft Hololens
		
HTC Vive Pro	Tablet	Magic Leap One

3.5 *Practical Applications:*

There can be various practical applications of VR/AR/MR in the construction industry. The application of these technologies depends on the requirements of users. Some of the practical applications are noted below:

1) Designers can employ VR to provide an immersive experience of a design to the clients for rapid decision making and approvals [13]
2) VR can be used to have a fair idea of spatial availability of a facility by having an immersive walk through [16]
3) AR is useful in terms of clients' meeting so that participants can see a 3D model to discuss for further refinement [17]
4) MR can be adopted for workers to improve productivity at the job site by providing the necessary information to perform a task when it is required [8]
5) AR/MR can be utilized to place 1:1 3D holographic model of a facility on-site, among its surroundings, at the pre-construction phase to ponder upon different design options for the optimum suitability [8]

3.6 *Research Gaps:*

As these technologies are developing, thus, there are many aspects that need to be studied. However, top four aspects are highlighted in this section.

1) Firstly, indeed different industries are adopting these technologies at their own pace, nevertheless, adoption of these technologies still requires cost-benefit analysis to make a strong case in terms of profitability [14].

2) Secondly, in the case of the construction sector, where stakeholder i.e. consultant, contractor and/or client should employ these technologies to get the most out of it in terms of cost and value.

3) Thirdly, most of the studies are conducted to explore or investigate the technologies from a technical point of view; can these technologies facilitate effective project management is yet to be explored.

4) Lastly, it is also significant to know the limitations of the technologies, such as, software and hardware issues.

4 CONCLUSION

It is apt to state that VR, AR and MR, though new technologies, have a potential to change the way many industries work and AEC is no exception. The construction industry can also benefit from these technologies in terms of design creation, decision making, visualization, health and safety trainings. However, promising prospects, as stated by the developers of these technologies for obvious reasons, are still under examination by academicians and industrial experts. Furthermore, cost-benefit analysis is yet to be taken to provide a strong business justification to invest in these technologies and associated roles to make it a practical and profitable adoption.

REFERENCES

[1] T. O. Oladinrin, D. R. Ogunsemi, and I. O. Aje, "Role of construction sector in economic growth: empirical evidence from Nigeria". FUTY Journal of the Environment. Vol. 7 (1): 50-60. http://dx.doi.org/10.4314/fje.v7i1.4, 2012.

[2] W. S. Alaloul, M. S. Liew, N. A. W. A. Zawawi and I. B. Kennedy, "Industrial Revolution 4.0 in the construction industry: Challenges and opportunities for stakeholders." *Ain Shams Engineering Journal*, 11(1), pp.225-230, 2020.

[3] S. Changali, A. Mohammad, and M. Van Nieuwland, "The Construction Productivity Imperative." *[online] Available at: https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/the-construction-productivity-imperative [Accessed 11 April 2020]*, 2015.

[4] Y. Li, and C. Liu, "Applications of multirotor drone technologies in construction management", International Journal of Construction Management. Vol. 19 (5): 401-412. https://doi.org/10.1080/15623599.2018.1452101, 2019.

[5] KPMG: Global Construction Survey 2016. [online] Available at: https://assets.kpmg/content/dam/kpmg/xx/pdf/2016/09/global-construction-survey-2016.pdf [Accessed 23 June 2020].

[6] B. Hardin, and D. Mccool, "BIM and Construction Management: Proven Tools, Methods, and Workflows", *2nd Edition. Wiley Publishing, Inc., Indianapolis, Indiana. ISBN: 978-1-118-94276-5*, 2015.

[7] M. Tariq, "Exploring the Role of Building Information Modelling (BIM) for Delivering Successful Construction Projects". *In: 7th International Conference on Environmentally Sustainable Development*, 2017.

[8] A. DaValle, and S. Azhar, "An Investigation of Mixed Reality Technology for Onsite Construction Assembly." *In MATEC Web of Conferences* (Vol. 312, p. 06001). EDP Sciences, 2020.

[9] P. Milgram, H. Takemura, A. Utsumi, and F. Kishino, "Augmented reality: A class of displays on the reality-virtuality continuum." *Telemanipulator Telepresence Technol. 2351: 282–292*, 1994.

[10] J. C. Cheng, K. Chen, and W. Chen, "State-of-the-Art Review on Mixed Reality Applications in the AECO Industry". *Journal of Construction Engineering and Management*, 146(2), p.03119009, 2020.

[11] L. Muñoz-Saavedra, L. Miró-Amarante and M. Domínguez-Morales, "Augmented and Virtual Reality Evolution and Future Tendency". *Applied Sciences, 10(1), p.322*, 2020.

[12] L. F. De Souza Cardoso, F. C. M. Q. Mariano, and E. R. Zorzal, "A survey of industrial augmented reality." *Computers & Industrial Engineering*, 139, p.106159, 2020.

[13] M. A. Tariq, U. Farooq, E. Aamir, and R. Shafaqat, "Exploring Adoption of Integrated Building Information Modelling and Virtual Reality". *In 2019 International Conference on Electrical, Communication, and Computer Engineering (ICECCE) (pp. 1-6). IEEE*, 2019.

[14] M. Noghabaei, A. Heydarian, V. Balali, and K. Han, "Trend Analysis on Adoption of Virtual and Augmented Reality in the Architecture, Engineering, and Construction Industry". *Data, 5(1), p.26*, 2020.

[15] Harvard Business Review, "MIXED REALITY: A NEW DIMENSION OF WORK." *[online] Hbr.org. Available at: https://hbr.org/resources/pdfs/comm/microsoft/MixedRealityNewDimensionOfWork.pdf [Accessed 28 May 2020]*, 2018.

[16] Stanton, Danaë, P. Wilson, and N. Foreman. "Using virtual reality environments to aid spatial awareness in disabled children." In Proceedings of the 1st European conference on disability, virtual reality and associated technologies, pp. 93-101. Maidenhead, England: University of Reading, 1996.

[17] Büscher, Monika, M. Christensen, K. Grønbæk, P. Krogh, P. Mogensen, D. Shapiro, and P. Ørbæk. "Collaborative augmented reality environments: integrating VR, working materials, and distributed work spaces." *In Proceedings of the third international conference on Collaborative virtual environments, pp. 47-56.* 2000.

DEVELOPMENT OF AUTOMATED RESOURCE MANAGEMENT SYSTEM (ARMS)

[a] Qasim Jilani Farooqi, [b] Muhammad Awais Ahmed, [c] Muhammad Hasnain, [d] Saad Adeel
a: Department of Construction Engineering and Management, School of Civil and Environmental Engineering, National University of Sciences and Technology, qjfarooqi.cem19@student.nust.edu.pk
b: Department of Construction Engineering and Management, School of Civil and Environmental Engineering, National University of Sciences and Technology mawais.cem19@student.nust.edu.pk
c: Department of Construction Engineering and Management, School of Civil and Environmental Engineering, National University of Sciences and Technology, mhasnain@nit.nust.edu.pk
d: Department of Construction Engineering and Management, School of Civil and Environmental Engineering, National University of Sciences and Technology, sadeel.bece15@nice.nust.edu.pk

Abstract- The efficiency of construction industry is measured by on time project completion. Unfortunately, most of the construction projects suffer time and cost overruns owing to complex nature of construction industry. To overcome this challenge, construction industry needs to incorporate automation and information technology (IT) application in various construction processes. Projects subsume enormous unmanned resources to undertake project tasks on time and conforming to the quality standards. Unscrupulous resource management leads to schedule slippage, poor budgeting and disputes among project stakeholders. The application of modern automated tools can make efficient information management and project data sharing alongside augmenting productivity. This research focuses to integrate automated communication system with resource management processes to improve overall project efficiency. Factors contributing automated resource management have been identified through extensive literature review. Further, the scrutiny of factors has been carried out by gathering responses from industry experts using a questionnaire. A framework for automated management of non-labor resources is developed based upon communication links and relative information flow of construction activities. This framework supports in developing a mobile application that allows construction personnel to request for resources, check request status and resource monitoring. This research signifies that automated resource management system entails efficient communication among participants and leads to auspicious project delivery.

Keywords- Communication System, Construction Database, Construction Automation, Resource management

1 INTRODUCTION

Efficiency of construction industry is considered as on-time delivery of construction projects with minimal cost over-runs [1]. Unfortunately, many projects suffer delays and require plethora amount of resources to complete. With augmenting the complexity of construction projects, there likelihood of cost and time over-runs are increased. The complex nature of projects can be controlled efficiently with application of modern technology. From manual drafting to Building Information Modelling (BIM) and from manual labor work to use of heavy machinery, construction industry has made fortuitous progress in technological applications. There exists a broad gap to integrate technology in various domains of construction industry like risk improvement, communication and project controlling [2].

Proper communication and automated monitoring systems can help in increasing efficiency of construction practices [3]. Lack of adequate communication mechanisms, ineffective reporting system and facile data channels are the aftermath in terms of lower productivity and poor project performance. Additionally, emotional interference and physical barriers have proved to be problem in communication. On construction sites, people from different linguistics backgrounds communicate with each other. There is a need to address and overcome these barriers so to avoid miss-communication and to harmonize human resource interaction [4].

Construction industry is mainly relying on manual work for technical purposes and paperwork for documentation. Information through conventional channels gets dissipated easily thus causing delay in material delivery, extra cost and lower productivity. In recent years, incorporation of information technology in different industries is an indication for construction professionals to adopt modern informatics tools to bolster communication database. Construction industry has incorporated information technology in different domains. Although, resource management system requires enough improvement on construction projects to ensure transparent communication among project participants. Therefore, automated, user friendly and sustainable resource management is a viable option to improve the current system [5]. The main objective of this research is to identify resource management factors causing time and cost overrun via consulting experienced professionals and development of a framework that encompasses communication, resource management and inventory management for construction sites. This framework engenders the development of mobile based application for automated management of unmanned resources on construction projects.

The findings of this study will redound to the benefit of construction industry considering that technology plays an important role in every industry today. Different factors causing time and cost overrun in construction industry were analyzed and identified after extensive literature review and consulting experienced professionals. Those factors help in developing a Framework covering communication, resource management and inventory management for construction sites. This framework can be used as basis for development of mobile application that will manage communication and resource management on construction sites.

2 LITERATURE REVIEW

Resource management and planning is considered one of the most important factors to ensure profitability and competitiveness in the current construction industry. Building materials and equipment entail almost up to 50-60% of the overall project cost [4]. In the broader aspect, the construction industry has made advancements in processes like design, planning and management. Despite these advancements, the construction industry is typically slow to adopt changes and there is a need to dig deep on substantial issues like on-site tracking and monitoring of unmanned resources.

The average time over-run on any project is between 10-30% of the original duration assigned. This statement was agreed upon by 76% of the contractors and 56% of consultants [6]. Lack of effective communications on site, material shortages and improper planning causes delays in construction projects [7]. Poor resource management is responsible for schedule slippage and cost overrun [8]. US National research council (NRC, 2009) also stated that to improve the overall competitive nature of construction industry the project schedules, labor and construction materials should be managed much more effectively.

Different researchers have identified factors causing problems like time and cost overruns in relation to on-site resource management. These problems arise due to mismanagement of responsibilities by each stakeholder like client, contractor and consultant[2, 9]. The factors identified are categorized accordingly stating stakeholder responsible for the said problem. The major factors causing problems, identified by these researchers are listed below: -

Table 1-Resource management Factors effecting Time & Cost overruns

Responsibilities	Factors
CLIENT	Change in the scope of the project
	Delay in progress payment by owner
	Financial difficulties of owner
	Delays in decisions making
	Owner interference
	Unrealistic contract duration and requirements imposed
CONSULTANT	Delay in inspection and approval of completed works
	Unrealistic contract duration and requirements imposed

	Frequent design changes
	Mistakes and Errors in design
	Delay in Preparation and approval of drawings
	Incomplete design at the time of tender
CONTRACTOR	Inadequate planning and scheduling
	Lack of experience
	Poor site management and supervision
	Incompetent subcontractors
	Cash flow and financial difficulties faced by contractors
	Mistakes during construction
RESOURCE RELATED FACTORS	Fluctuation of prices of materials
	Shortages of materials
	Late delivery of materials and equipment
	Insufficient Numbers of equipment
	Labor Productivity
	Shortage of site workers

2.1 Use of Information Technology on Construction Sites

Information and Communication Technology (ICT) is increasingly being considered for versatile use in planning, design and project monitoring. Its use in data collection, life cycle assessment, and monitoring and controlling is a significant contribution to the advance knowledge and practice of ingenious decision making. Continuous access to information, communication and finances control, project data accessibility and reduced number of errors in documentation are the major benefits of using ICT [10]. Some of the technologies that can potentially help in designing framework were studied in detail and are as follows: -

2.2 Automated Data Collection Devices (ADCs)

These devices are being used commonly in the logistics and manufacturing industry and can make project operations easier on construction site [10]. According to [11], increased efficiency, reduction in the number of data entry errors and a reduced labor cost can be achieved with the use of ADC technologies. This has been augmented a lot using affordable cellphones which are accessible to almost everyone now and are being used holistically in industrial and commercial sectors. This will pave the way forward to implement automated construction techniques and aid job-site practitioners to get connected by using ADCs or personal cellphones. This method can help in reducing time and cost incurred by construction sites. [12].

2.3 Radio Frequency Identification (RFID) Tags

Radio-frequency identification (RFID) tags use radio waves to access information stored on a readable object. A tag can be accessed from several feet away. RFID tags are being used commonly in many industries and can also be used to increase efficiency on construction sites [13].

2.4 Quick Response (QR) Codes and Scanner

QR codes are a form of two-dimensional barcodes that can be read easily by an optical reader. Information stored in a QR code usually points towards a website or an application. This system is very easy to use and has a relatively larger storage capacity which leads to its comparison with the Universal Product Code (UPC).

2.5 Prospects

FIATECH is a non-profit consortium that has developed a technology roadmap for construction industry where they have focused on the concept of "Intelligent and automated construction site" which consists of the following ideas [14]:

- Tracking of material and non-material resources on site.
- Increase in the efficiency and productivity of the construction workers.
- Continuous flow of materials will be augmented using on-site tracking systems.
- Enabling construction workers to instantly locate required resources.

3 RESEARCH METHODOLOGY

3.1 Overview

The research methodology encompasses the development of an automated resource management system based on effective communication planning and mobile application. The main purpose of this mobile phone application will be to reduce the time consumed in manual record keeping, requesting material on-site, requesting the required machinery and to monitor the stockpile of resources available for use.

3.2 Identification of Factors

Effect of construction resource monitoring on project costs and time were studied. For this purpose, a detailed literature review is conducted to identify factors related to project cost and time with resource monitoring and controlling.

The major factors identified are as follows:

- Miscommunication
- Misinformation
- Extensive paper use
- Difficult record keeping
- Misplaced materials
- Shortage of materials
- Delayed delivery of materials to site
- Non availability of materials and equipment
- Delay in material procurement
- Lack of communication

3.3 Design of Questionnaire & Site Surveys

In next step, a detailed questionnaire was developed, and responses were gathered from relevant industry professionals. This questionnaire was used to draw input from the field experts on how technology can be materialized to eradicate problems relevant to resource management. This questionnaire aided in the identification of experts' needs and their willingness to adopt an automated resource management system. The Survey questionnaire used open ended questions to get true picture of prevailing situation at our construction sites. Further, these factors were shortlisted based upon their relative frequency that effect resource monitoring on construction sites. The outcome of this research assists in identification of proper communication channels and standard operating procedures in construction projects. Following parameters were assessed in different parts of the questionnaire:

- How on-site material requests were being handled?
- How on-site machinery requests were being handled?
- How procurement was being managed?
- How on-site communication was being done?
- How automation can be integrated in our current practices?

A detailed and comprehensive survey was conducted at various construction sites within cities of Rawalpindi and Islamabad. Detailed survey has been conducted from construction professionals working on different infrastructure and mega projects including residential societies, metro bus, roads and building projects. The sample size appropriate for such a study was calculated using the sample size calculator developed by creative research systems [9]. A total of 72 responses were gathered with 95% confidence interval. The survey was distributed to construction experts who have experience in adopting latest technologies in their projects.

3.4 Framework Design

In the first step of framework design, the critical factors were defined as input which extracted from site surveys. The communication framework included planning of the information flow channels, requests for the required machinery, information flow about availability of the construction machinery, requesting construction materials and record keeping of available materials in the construction yard. For this purpose, different modules were designed and each module was specified to a user having different functionality according to their needs. The basic outline of the design is as follows:

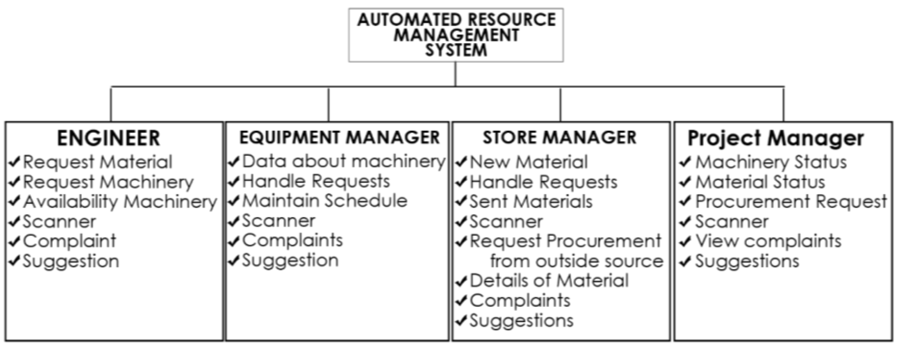


Figure 1: Activities available to each professional in the ARMS app

Figure 1 shows details about activities and options available to each professional working on construction site. As mentioned earlier every professional was assigned a specific module according to his need, role and responsibility making it a user-friendly application for every construction professional. For example, requesting material and machinery, checking availability of material and machinery and complaint/ suggestions are options which are essential for proper working of engineer on construction site. But Engineer does not need to know details about procurement of materials which is included under store manager module.

4 RESULTS

A survey was conducted to analyze the identified factors. Total number of 72 responses was received. Survey questions were focused to get the insight depth and identify root cause of the problem. Professionals working with different stakeholders like client, contractor and consultant were approached. The respondents were equipped with average experience of 10 to 20 years in construction industry. 96% of the professionals agreed that time and cost overruns are serious problems for construction industry. It was found that at least 62% of the times projects suffer time and cost overrun. According to survey conducted, improper management of material and machinery are one of the leading factors causing time and cost overrun.

A person generates or handles more than 20 requests per day working on site. In consequence, surplus paper is used in making these requests. Site engineer is not notified about status of their requests for material and machinery which causes confusion and delays in their relevant tasks. On average 60% of the time a required material is not available or delayed in construction yards. This indicates that proper inventory management techniques are not being used. It clearly demonstrates that manually driven tasks subsumes plethora of resources. The outcome of this study shows that Automated Inventory management systems will alert the store/ procurement manager to procure required material prior its shortage.

Almost all of the respondents agreed to the envisaged approach that Record Keeping using automated application will take lesser time and will be easier to manage. Computerized cloud-based storage system stores data for longer period and finding a record is easier as compared to manually maintained records system. On the contrary, large number of tiers involved in making a request to procure material from outside source utilizes large amount of time.

4.1 Framework for Development of Mobile Application

Based on Survey results, a framework was developed. The developed framework for mobile application substantiates an integrated approach to abate extra time and cost considering resources with their integrated roles. Many industry professionals emphasize the need of adopting integrated technological application on construction projects. The proposed framework primarily focusses on augmenting communication among team members in a coordinated and systematic way. The framework also caters organization culture, human disposition and stakeholder expectation. This framework can be implemented in many industries and market segments. This Framework will be used for development of mobile application.

The mobile application developed will help in generating requests, checking status on requests, managing procurement, onsite communication and problem solving. The framework will solve following problems in the mentioned ways: -

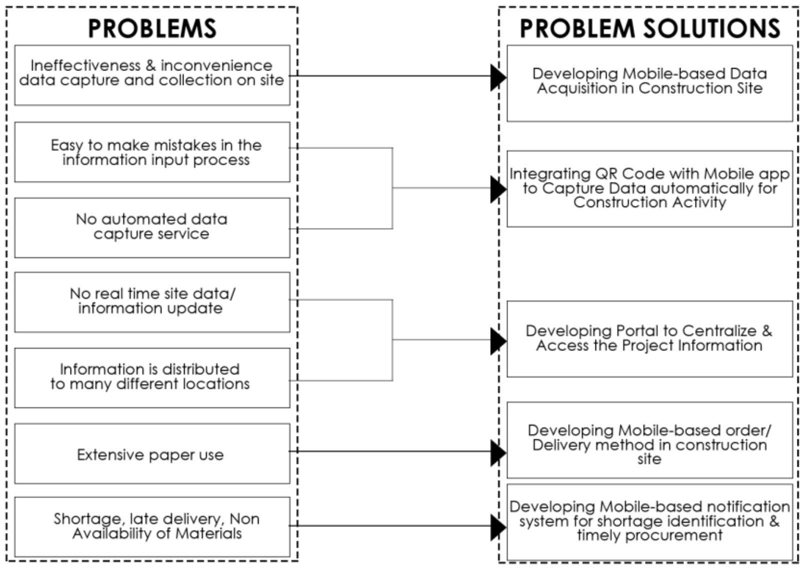


Figure 2: Planned Solution of Different Problems in Framework

Figure 2 includes planned solution for different problems that were identified in the survey. For example, ineffective and inconvenient data capturing on construction site can be catered by using mobile based data acquisition. Chances of making mistakes is reduced by providing automated data capturing service using QR code with proposed mobile application. Centralised portal for accessing project information helps in providing real-time site data and collection of information at one location.

4.2 Practical implementation

Implementation of proposed framework and mobile based application is much easier as almost every person uses android or iOS based mobile devices. Availability of QR scanner in mobile phones and easy to produce QR codes has made it possible to implement the suggested mobile application. Use of existing technologies for our help makes it easier and economical to implement this study.

5 CONCLUSION

A Framework was designed for development of mobile application after elaborated field survey to identify major resource administrative issues being faced on construction sites. A proper schematic framework is designed to automate the on-site management system. This framework used automation techniques like mobile applications, QR codes and RFID tags to deliver the progress information swiftly. On-site personnel are given access to the information providing ease of operation and data sharing. According to survey conducted, on average a single construction professional handles about 20 requests for material daily that amounts to around 6000 pieces of paper yearly per person. A great reduction in paper consumption can be achieved with automated on-site resource management system.

The developed automated system will accelerate the material approval process from hierarchy of members and help in overcoming communication barriers. Additionally, earlier material procurement can be ensured prior to its shortage that consequently save huge amount of time in resource acquisition. The framework developed in this research can be used to design a mobile application which will handle requests for material and machinery, check availability status, site staff can track requests and make complaints/ give suggestions about any problem being faced. Besides this, the framework should be linked to planning software like Primavera P6 and MS Project and notification system should be developed which sends notification to check material availability prior to start of any activity. Moreover, management of manned resources can be integrated in this mobile application.

ACKNOWLEDGMENT

The authors would like to thank every person/ department who helped thorough out the research work, particularly CE&M department of NUST, especially Dr. Muhammad Jamaluddin Thaheem for his prodigious support and guidance. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] S. Bowden, A. Dorr, T. Thorpe, and C. Anumba, "Mobile ICT support for construction process improvement," Automation in Construction, vol. 15, pp. 664-676, 2006.
[2] V. Ahuja, J. Yang, and R. Shankar, "Study of ICT adoption for building project management in the Indian construction industry," *Automation in Construction,* vol. 18, pp. 415-423, 2009.
[3] Xinhai-lu, "PROBLEMS OF PROJECTS AND EFFECTS OF DELAYS IN THE CONSTRUCTION INDUSTRY OF PAKISTAN " 2011.
[4] S. Durdyev, M. Omarov, S. Ismail, and S. K. Shukla, "Causes of delay in residential construction projects in Cambodia," *Cogent Engineering,* vol. 4, 2017.
[5] S. S. S. Gardezi, I. A. Manarvi, and S. J. S. Gardezi, "Time Extension Factors in Construction Industry of Pakistan," *Procedia Engineering,* vol. 77, pp. 196-204, 2014.
[6] S. A. Assaf and S. Al-Hejji, "Causes of delay in large construction projects," *International Journal of Project Management,* vol. 24, pp. 349-357, 2006.
[7] S. Moon, S. Xu, L. Hou, C. Wu, X. Wang, and V. W. Y. Tam, "RFID-Aided Tracking System to Improve Work Efficiency of Scaffold Supplier: Stock Management in Australasian Supply Chain," *Journal of Construction Engineering and Management,* vol. 144, p. 04017115, 2018.
[8] H. Li, G. Chan, J. K. W. Wong, and M. Skitmore, "Real-time locating systems applications in construction," *Automation in Construction,* vol. 63, pp. 37-47, 2016.
[9] K. N. Hewage and J. Y. Ruwanpura, "A novel solution for construction on-site communication – the information booth," *Canadian Journal of Civil Engineering,* vol. 36, pp. 659-671, 2009.
[10] J. M. Sardroud, "Perceptions of Automated Data Collection Technology Use in the Construction Industry," *Journal of Civil Engineering and Management,* vol. 21, pp. 54-66, 2014.
[11] J. Irizarry, E. P. Karan, and F. Jalaei, "Integrating BIM and GIS to improve the visual monitoring of construction supply chain management," *Automation in Construction,* vol. 31, pp. 241-254, 2013.
[12] N. Kasim, "Intelligent Materials Tracking System for Construction Projects Management," *Journal of Engineering and Technological Sciences,* vol. 47, pp. 218-230, 2015.
[13] E. Valero, A. Adan, and C. Cerrada, "Evolution of RFID Applications in Construction: A Literature Review," *Sensors (Basel),* vol. 15, pp. 15988-6008, Jul 3 2015.
[14] D. C. Pinha and R. S. Ahluwalia, "Flexible resource management and its effect on project cost and duration," *Journal of Industrial Engineering International,* vol. 15, pp. 119-133, 2018.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

ACHIEVING THE SUSTAINABILITY IN CONSTRUCTION BY USING ARTIFICIAL AGGREGATES IN CONCRETE

Zeeshan Ullah[a]*, Engr. Sami Ullah[b] , Engr. Muhammad Sarwar[c], Engr. Shah Jahan[d], Engr. Muhammad Irfan[e]
a: PhD student, Dept. of Construction Engineering & Management (CE&M), NIT, SCEE, NUST, Islamabad, Pakistan
zeshan880@gmail.com
b: Assistant Director, TEPA, LDA, samigondal.lda@gmail.com
c: Assistant Engineer, University of Jhang, ayyansarwar273@gmail.com
d: Assistant Professor, University of Lahore, Gujarat Campus, *Shahjahan1002@gmail.com*
e: Lab Engineer, Civil Engineering Department, KFUEIT Rahim Yar khan, *engr.mirfan1992@gmail.com*

Abstract: Environmental issues compel construction experts to search materials that do not pose hazard to environment. Reduction of natural resources and higher density of natural aggregates results in production of dense concrete that increase dead load, and hence overall building cost. Therefore, cost effective and lightweight concrete mix can resolve these problems. The aim of this research is to choose the best locally available material to produce cost effective lightweight concrete which has required strength, lesser density, electrical conductivity, and thermal conductivity as compare to normal weight concrete (NWC). For this purpose, three types of sample were taken to evaluate compressive strength, thermal conductivity, and electrical conductivity. First sample was made by using bloated Shale from Islamabad, Lahore, and Peshawar, second one by using bloated Shale from Karachi and third one by using bloated Slate from Peshawar and these samples were used as replacement of natural aggregate in concrete. Concrete samples were tested for strength, electrical conductivity, and thermal conductivity. The strength and other properties were used to design the multistory building to check variation in member sizes and hence cost. These tests showed that, the particle size of artificial lightweight aggregates is larger than particle size of natural aggregates that will helpful in improving strength of concrete. Bulk density of artificial lightweight aggregates in loose state is only 70% of that of natural aggregates and similarly bulk density of artificial lightweight aggregates in compact state is around 68% of that of natural aggregates. Thermal conductivity of artificial lightweight aggregates concrete is 1.030 which is around 49% of that of normal concrete. The electrical conductivity of artificial lightweight aggregates is 0.141 which around 16% lesser than electrical conductivity of normal concrete. Normal weight concrete has the highest strength and shale Karachi with 10% sawdust has the lowest strength. On basis of pairwise comparison putting their relative scores in the software and result extracted from the software shows that NWC is best alternative with respect to compressive strength. The artificial light weight aggregate concrete has lesser energy demand, better comfort level and lesser structural cost compare to normal weight concrete. As artificial light weight produced in lesser amount therefore, manufacturing cost of these aggregate is higher than normal aggregate.

Keywords: Energy Performance, Normal Concrete, Lightweight Concrete, Natural Aggregates, Artificial Lightweight Aggregates, Human Comfort.

1 INTRODUCTION

The intense climate change in the last decade has led to increased problems for society and environment. Due to increase in environmental issues, construction industry is continuously in searching for materials which reduce both the energy and carbon emission in buildings. Energy consumption from buildings is heavily affecting environment, as 90% of impact is causing by energy consume by building [1]. According to U.S. Green Building Council "About 40% of world's energy is consumed by buildings and this value is way more than that of energy consumption by transportation and other construction sectors. In next 25 years, amount of CO_2 emission is going to be increase from building sector as compared to any other sector, with an average increase in 1.8% per year from commercial sector in USA". Reducing this building energy consumption will prove significant in reducing environmental impact [2]. Therefore, structures must be designed in such a way that they have a least environmental impact over their lifetime, while fulfilling normal level of comfort and durability for inhabitants. Sustainable development of buildings reduces use of energy, land, water, raw materials, and many resources. It also decreases greenhouse gases emission, thus reducing the impact of pollution in environment and thus safeguarding people's health. By increasing the efficiency of buildings with the help of sustainable construction will result into energy efficient building thus causing money saving, longer life span of buildings and least maintenance and operation cost [3].

Main problem confronted by construction industry is dense concrete production resulting in increased dead load, and problem in transportation/ handling. There is a need of cost effective and lightweight concrete mix that resolves these problems. This research provides solution to these problems along with significant compressive strength using naturally available artificial lightweight aggregates. The primary aim of this project is to provide an efficient strength to weight ratio by production of structural lightweight concrete that reduces dead load and design size of concrete. Therefore, for sustainable construction, artificial lightweight aggregates are chosen for production of lightweight concrete with 10%, 20%, 50% and 100% replacement with natural aggregates.

The aim of this study is cost comparison of concrete framed commercial building using natural and artificial coarse aggregates and also to choose the best locally available material to produce lightweight concrete which has required strength, lower cost, density, electrical resistivity, and thermal conductivity than normal concrete. Low density means less dead load and hence reduced size of members which reduces overall cost. Low thermal conductivity leads to energy efficient housing thus causing money saving, longer life span of buildings. Reducing this building energy consumption will prove significant in reducing environmental impact [4].

For this purpose, three types of sample were taken to evaluate compressive strength, thermal conductivity, and electrical conductivity. First sample was made by using bloated Shale from Islamabad, Lahore, and Peshawar, second one by using bloated Shale from Karachi and third one by using bloated Slate from Peshawar and these samples were used as replacement of natural aggregate in concrete. Concrete samples were tested for strength, electrical conductivity, and thermal conductivity.

2 LITERATURE REVIEW

The future of this planet is a matter of concern. Environmental issues and how human communities affect ecosystem concerns have been part of human society from the beginning. Because of deterioration of environmental conditions in many parts of the world, sustainable development has become a recognized goal for human society. Therefore, humanity has to pay more attention to the environment [5].

For several years, lightweight high strength concrete has been used productively for structural objectives. The research has presented that it can be possible to make lightweight concrete by using Lightweight Expanded Clay Aggregates (LECA) with 10 % silica fume which achieved 70.5 MPa compressive strength having 1,860 kg/m³ density [6]. Some studies have shown that lightweight concrete with 43.8 MPa 90 day's compressive strength and dry density 1,860 kg/m³ can be produced by using basalt-pumice as coarse aggregates [7].

Many studies have been carried out on different aspects of artificial lightweight aggregates such as manufacturing of artificial lightweight aggregates [8], properties of artificial lightweight aggregates [9], comparison between natural and artificial coarse aggregates in concrete mixture [10] and so on. But this study is focusing on comparison of framed concrete commercial building using natural and artificial lightweight aggregates.

3 LIGHTWEIGHT CONCRETE AND ITS PROPERTIES

Manufacture of lightweight structural aggregates concrete (LWSAC) involves using of variety of lightweight aggregates. Lightweight structural aggregates concrete (LWSAC) fulfills to the standard "it should have a least compressive strength of 17.5 MPa nearly equal to 2500 Psi at 28 days and it should have a dry density value ranging 1120–1920 kg/m^3". Those aggregates whose particle density is not greater than 2000 kg/m³ or loose bulk density is not greater than 1200 kg/m³ are termed as lightweight aggregates (LWA) [11].

Lightweight aggregates can exist naturally or can be made artificially using industrial processes [12]. The properties of lightweight concrete like strength, thermal and acoustic insulation depend on type of aggregates used for its production. Therefore, consideration of properties of aggregates is very important for manufacture of lightweight concrete. Most of countries are manufacturing light weight expanded aggregates called light expandable clay aggregates (LECA), using some clay which can expand called bloated clay. This clay is heated in a horizontal rotary kiln at about 1200 degree Celsius, using wet process. In this process paste of water and clay is made which is then fed into the kiln where it is broken into smaller granules, resulting into formation of porous structure [13].

High porosity is the main property of artificial lightweight aggregates, which results into low specific gravity. Strength of artificial lightweight aggregates particles depends on source and type of aggregates. The strength of concrete is not dependent on the strength of coarse aggregates since there is no exact relationship between aggregates strength and concrete strength. Generally, compressive strength of concrete is related to content of cement at a given particular slump instead of water to cement ratio (w/c). In some cases, compressive strength can be increased by using good quality natural sand in place of fine light weight aggregates. The normal weight aggregates zone is stronger in conventional concrete as compared to interfacial transition zone (ITZ) and cement matrix. Contrary to that, introduction of artificial lightweight aggregates in concrete mixture significantly affects mechanical and elastic properties of lightweight concrete, since they are the weakest constituents [14].

Literature tells that strength of concrete is determined by its weakest component. Stress transfer takes place through aggregates and mortar, when aggregates are rigid constituent. If aggregates are weak, then transfer of stresses occurs through cement matrix, resulting into cracks propagation throughout artificial lightweight aggregates particles. This suggest that artificial lightweight aggregates itself is weaker than interfacial transition zone (ITZ) [15]. Therefore, density and volume of constituent artificial lightweight aggregates is very important to get results comparable with normal weight concrete [16].

Lightweight concrete is subjected to more creep and shrinkage as compared to equivalent normal concrete cylinder. Such factors should be considered during the design process [17]. The significance of using light expandable clay aggregates (LECA) in concrete mix is better bond formation between mix constituents. The "Wall Effect" which is related to particle packing does not exist on surface of expanded clay aggregates in lightweight concrete by scanning electron microscopy (SEM) and back scattered electron imaging (BSEI), resulting in a better bond and much thinner interfacial zone than normal concrete [18].

Expandable light weight aggregates have better thermal resistivity and insulation as compared to normal concrete because of lower coefficient of thermal expansion, lower thermal conductivity, and fire stability since they are made by heating at very high temperatures of 2000^0F. Lower thermal conductivity causes exposed members to achieve a steady state temperature at a higher time, thus decreasing internal temperature changes. This time difference lag moderate nightly cooling effect and solar buildup in buildings. Such property can be useful in tall buildings where exposed lightweight columns have no large volume and stresses variations due to lower coefficient of thermal expansion [19].

4 RESEARCH METHODOLOGY

One of the main reasons of environmental problems is energy consumed by the construction industry. Therefore, a detailed literature review was carried out to identify different solutions. One of the main challenges in sustainable design of buildings is to improve the energy efficiency of the building during its lifetime along with reducing the environmental impact of the design. Concrete is the most widely used construction material in the building industry and consumes the second highest amount of natural resources [20]. In order to make concrete more environmentally sustainable, it should be energy efficient. Thermal conductivity is the most influencing factor in energy efficiency of concrete. Thermal conductivity of concrete is dependent on type of aggregates used in the concrete mixture. Some published construction properties databases associate thermal conductivity to concrete density. Therefore, it is possible to make concrete more energy efficient by replacing natural aggregates with low density artificial lightweight aggregates. The value of thermal conductivity of concrete is decreased by 0.13Wm-1K-1 with the introduction of artificial lightweight aggregates in concrete and proven by the research work. Properties other than thermal conductivity were also studied.

4.1 Choice Of Aggregates

The choice of aggregates is very much related to a local supply chain. So, in this study the best locally available aggregates to produce lightweight concrete which has required strength, minimum cost, low density, thermal conductivity and electrical resistivity. As the most important property, is its lightweight, which will result into decrease in dead load, thus enabling the use of lightweight foundations, reducing cost in handling and transportation, and enhancing the time of construction. Decrease in dimensions of structural members and good thermal and acoustic insulation can be achieved from its low density. Increased cost of artificial lightweight aggregates can be covered based on its ease in handling, less energy requirement in demolishing, less waste requirement and high durability due to the strong bond of aggregates. After identification of properties, availability of artificial lightweight aggregates was located. Artificial lightweight aggregates were chosen for further research.

Slate for was extracted from Manki Formation (95 km from Peshawar city). Manki Formation is characterized by metamorphic rocks from Precambrian age e.g. slate, quartzite and phyllite. Raw slate used in this research was fine grained rock split into thin broad sheets with gray to black color. The slate is a normal weight aggregates but it is converted into a lightweight aggregate by expanding it.

In carrying out the process, slate was prepared by reducing it to a finely divided state, mixing it with the bloating agent, and with suitable amounts of water to impart sufficient plasticity, and shaping it into individual particles as by extrusion and division into desired lengths. Exact pre shaping of the particles is, however, unnecessary and it is sufficient to break up the slate into particle sizes correspondingly smaller than the desired bloated size. The size of the particles will therefore vary considerably but generally it is preferred that they have a size distribution such that when bloated will yield artificial lightweight aggregates conforming to the prevailing specifications in the industry. In the preparation of slate's, it is necessary only to roughly size the slate. Those slate's, which do not naturally bloat, must be reduced to a fine powder, and mixed with a bloating agent before shaping. Slate may be prepared similarly to a non-bloating slate by reducing it to a fine powder, mixing it with a bloating agent and shaping [21].

Artificial lightweight aggregates, expanded slate was yielded in PCSIR (Pakistan Council of Scientific and Industrial Research) Peshawar through processing of natural aggregates in rotary kiln method. The chemical composition of shale Karachi is, 37-60% weight of $Si0_2$, 15-26% weight of $A1_2O_3$ + $Ti0_2$, 3-13% weight of Fe_20_3, 11-16% weight of alkaline earths (CaO+MgO) and alkalies (Na_20+K_20) and loss on ignition 3.94%. The chemical composition of shale Peshawar is, 59.07% weight of $Si0_2$, 0.57% weight of $A1_2O_3$ + $Ti0_2$, 15.85% weight of Fe_20_3, 10.25% weight of alkaline earths (CaO+MgO) and alkalies (Na_20+K_20) and loss on ignition 3.87%.

4.2 Formulation Of Concrete Mix Design

Five formulations were designed. Following were the quantities for the respective mixes:

1. N100 (using 100% natural coarse aggregates) (Normal Weight Concrete)
2. Shale Karachi with 10% Sawdust
3. Shale Karachi
4. Shale Peshawar
5. Slate

5 RESULTS AND DISCUSSIONS

5.1 Compressive Strength Test

Six cylindrical samples (6"x12") for each artificial (10%, 20%, 50% & 100%) and natural (100%) aggregates were casted and tested at 07 and 28 days for compressive strength. In this method, cylinders were subjected under axial compressive load for some time until the sample fails. The maximum load, which was attained by sample before its failure, was divided by the sample cross section area to get compressive strength of sample. (ASTM C 39). Six cylindrical samples (6"x12") for each artificial (10%, 20%, 50% & 100%) and natural (100%) aggregates were casted and these samples were casted and tested at 07 and 28 days splitting tensile strength. Basically, in this method we were calculated indirect tensile strength of the concrete. (ASTM C 496/C 496M).

Test results for compressive strength are shown below in Fig-1. Normal weight concrete has the highest strength and shale Karachi with 10% sawdust has the lowest strength. On basis of pairwise comparison putting their relative scores in the software and result extracted from the software shows that NWC is best alternative with respect to compressive strength.

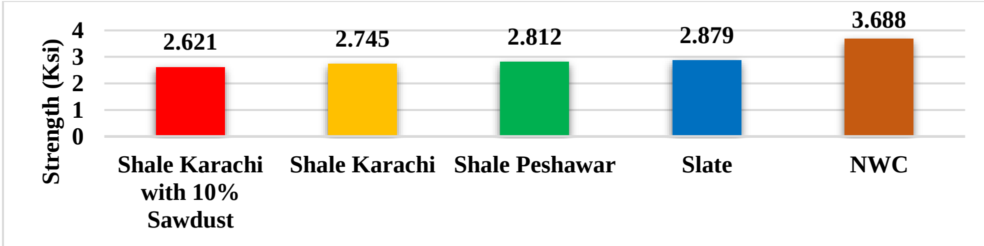


Figure 50: Compressive strength test results

5.2 Thermal Conductivity

Six samples (2"x2"x2") in cube for each N100 and A100 of concrete were casted. The samples were further cut down to a size of (2"x2"x1") in as it is the requirement of the apparatus. The samples were sent to NED University Karachi for testing of thermal conductivity. The thermal conductivity test was done by using guarded heat flow meter.

In this test a sample and a heat flux sensor, which is a transducer (HFT), is placed between two plates, having controlled different temperature, which causes heat flow. To ensure the proper contact resistance between sample and surface of the plate, test application is subjected to some load through some pneumatic mean. To minimize the heat losses, a guard is used around the plates, which is maintained at the mean temperature of plates. The difference in temperature between the surfaces is measured with the help of the sensors, which are placed in plates along with the heat flux transducer electrical output. This electrical output voltage is directly proportional to the heat flow through the specimen. Before taking any measurement, calibration of the instrument is done with the help of the sample of known value of thermal resistance to obtain the proportionality. (ASTM E1530 – 11).

Results for thermal conductivity are shown below in Fig-2. Normal weight concrete has the highest thermal conductivity and Slate has the lowest Thermal Conductivity. Lesser the thermal conductivity lesser will be heat passed through building hence results in reduction in energy consumed by building [22]. On basis of pairwise comparison putting their relative scores in software and graph extracted shows that Slate is the best alternative with respect to thermal conductivity.

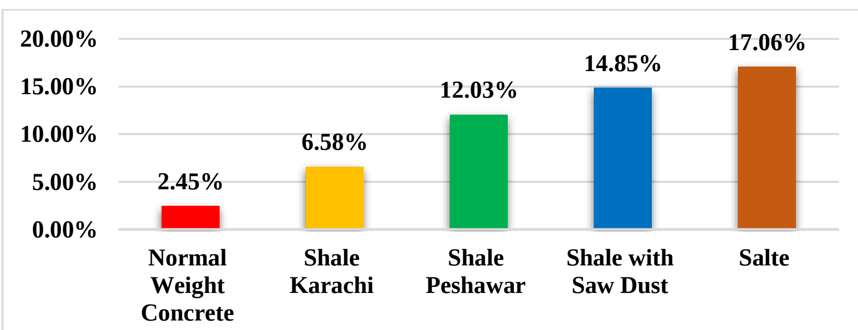


Figure 51: Comparison of samples on the basis of Thermal Conductivity

5.3 Electrical Conductivity

Six samples (2"x2"x2") in cube for each N100 and A100 of concrete were casted. The samples were further cut down to a size of (2"x2"x1") in as it is the requirement of the apparatus. The samples were sent to NED University Karachi for testing of electrical conductivity. The electrical conductivity test was done by using two electrode soil box method.

In this method, a sample is placed between two opposite faces of a box. A voltage is applied between two opposite faces of box, which act as electrode. Current start flowing between the electrodes, causing a voltage drop, which is measured. This voltage drop is proportional to the voltage by Ohms law. (ASTM G187 – 12a).

Resistivity (electrical conductivity) is measured with the help of the formula:

$$r = (a \times R)/D$$

where:

a = Area of cross section in cm^2

R = Sample resistance in ohms

D= Distance between electrodes in cm.

Electrical Conductivity test results are shown in Fig-3. It is cleared that normal weight concrete has the highest Electrical Conductivity and Shale Karachi with 10% sawdust has the lowest electrical conductivity.

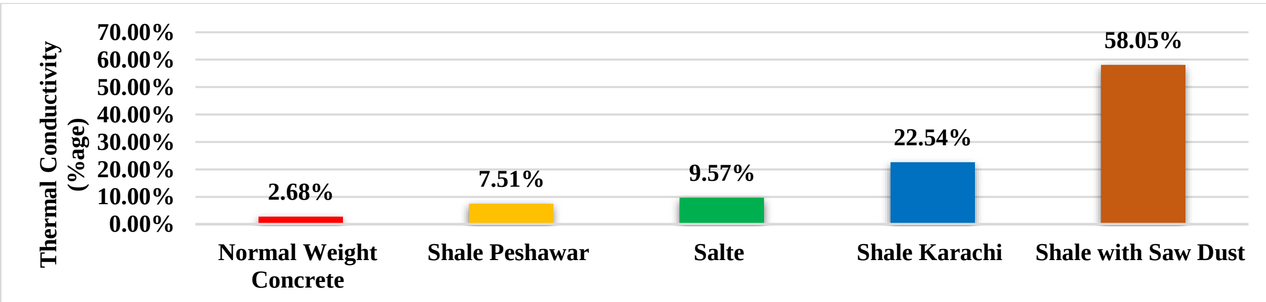


Figure 52: Comparison of samples on the basis of Electrical Conductivity

On the basis of pairwise comparison putting their relative scores in the software and results obtained shows that Shale Karachi with 10% sawdust is best alternative with respect to Electrical Conductivity.

6 Conclusions And Recommendations

In order to find out effect of ALWA on building performance and building demand, an attempt is made to evaluate effect of ALWA on thermal and electrical performance and hence on building demands. Following are major findings of this project.

1. From sieve analysis results it is clear that the particle size of ALWA is larger than particle size of NWA that will helpful in improving strength of concrete.
2. Bulk density of ALWA in loose state is only 70% of that of NWA and similarly bulk density of ALWA in compact state is around 68% of that of NWA. This lesser density will reduce the self-weight of concrete and also self-weight of overall building. This reduction in self-weight of concrete and overall building will reduce the members' size and hence reduce the overall cost of building.
3. The specific gravity of ALWA is only 1.88 which is 74% of that of NWA. This lesser specific gravity indicates lesser number of voids in concrete prepared with ALWA as compare to concrete prepared with NWA.
4. Thermal conductivity of ALWC concrete is 1.030 which is around 49% of that of NWC. Lesser the thermal conductivity of material lesser will be heat transformation and moderate will be the room temperature.
5. The electrical conductivity of ALWC is 0.141 which around 16% lesser than electrical conductivity of NWC. Lesser electrical conductivity of building better will be the comfort level of building.
6. The most influential factor is cost, cost of ALWA is very much higher than cost of NWA. It is because ALWA are not producing in bulk amount and hence manufacturing rate of small sample of ALWA are larger than the cost of natural aggregates.

After the comprehensive test results and suitable findings following conclusions are made for the stake holders as well as for the future research.

1. Pakistan is suffering from energy crises that is why building should be constructed using ALWA that will help in reducing energy demand of building and also improve building comfort level.
2. Awareness in stakeholders will increase demand of ALWA which helps in reducing production cost of ALWA.
3. Partial replacement (50%) gives better compressive strength without plasticizers than 100% replacement of ALWA but we can also use 100% replacement of ALWA after improving compressive strength using plasticizers.
4. Future research should be carried out but designing a particular building by using natural and ALWA and check how much cost will it save by conducting detail bill of quantities.
5. Life cycle costing and life cycle cost analysis should be carried out in future to find out variation in different phases and components of buildings.

REFERENCES

[1] Bakış, "Procedia - Social and Behavioral Sciences," Sustainability in Construction Sector, vol. 195, pp. 2253-2262, 2015.

[2] Bogas, "Compressive behavior and failure modes of structural lightweight aggregate concrete," Characterization and strength prediction. Materials & Design, p. 46, 2013.

[3] Claisse, "Chapter 19: Aggregates for Concrete and Mortar," in Civil Engineering Materials, 2016, pp. 177-188.

[4] Abul Bashar Emon, "Improving performance of light weight concrete with brick chips using low cost steel wire fiber," Construction and Building Materials, vol. 106, pp. 575-583, 2016.

[5] Petrullo, "Smart Market Report World Green Building Trends 2016: Developing Markets Accelerate Global Green Growth Smart Market Report.," 2017.

[6] Ramu, "Cost Comparison of Light Weight Aggregate Concrete by using Cinder," International Journal of Scientific Engineering and Research, vol. 4, No. 53, pp. 11473-11479, 2015.

[7] Tabassom Safikhani, "A review of energy characteristic of vertical greenery systems," Renewable and Sustainable Energy Reviews, vol. 40, pp. 450-462, 2014.

[8] V. Shami Nejadi, "Mix Design of Light-Weight Self Compacting Concrete," Case Studies in Construction Materials, vol. 4, pp. 1-14, 2016.

[9] Ch. Madhavi, "Electrical Conductivity of Concrete," ARPN Journal of Engineering and Applied Sciences, vol. 11, No. 1819-6608, 2016.

[10] Duran, "The Components of Sustainable Development-A Possible Approach," in Procedia Economics and Finance, 2015.

[11] Gravitt, "Eco-Efficient Construction and Building Materials," Constr. Manage., 2013.

[12] Mehrdad Massoud Nejad, "Investigating and Comparing the Economic Use of Normal Concrete and Lightweight Concrete in Iran," Journal of Current Research in Science, pp. 560-564, 2016.

[13] Katia Perini, "Vertical greening systems and the effect on air flow and temperature," Building and Environment, vol. 46, No. 11, pp. 2287-2294, 2011.

[14] K. Ding, "Sustainable construction—The role of environmental assessment tools," Journal of environmental management, pp. 86(3), 451-464, 2008.

[15] Ruveyda Komurlu, "Energy and Atmosphere Standards for Sustainable Design and," Energy and Buildings, Vol. 90, Pp. 156-165, 2015.

[16] J. Mohamed Muftah Mustafa, "Properties of Different Artificial Lightweight Aggregates and Their Effects on Concrete Strength," ARPN Journal of Engineering and Applied Sciences, vol. 11, No. 6, 2016.

[17] K. Erg¨ul YAS¸AR, "High Strength Lightweight Concrete Made with Ternary Mixtures," Turkish J. Eng. Env. Sci, vol. 28, p. 95 – 100, 2004.

[18] K. Mehdi Robati, "Incorporating Environmental Evaluation and Thermal Properties of Concrete Mix Designs. Construction and Building Materials," Construction and Building Materials, vol. 128, pp. 422-435, 2016.

[19] K. Norazila, An investigation on effect of quarry dust as sand replacement on compressive and flexural strength of foam concrete (Doctoral dissertation), Universiti Malaysia Pahang, 2010.

[20] L. Srinivasan.K, "An Experimental Study on Manufacturing of Artificial Aggregates Incorporating Fly ash, Rice Husk Ash and Iron Ore Dust," International Journal of Science, Engineering and Technology Research (IJSETR), vol. 5, No. 1, 2016.

[21] M. Ali Nobil Ahmad, "Useful daylight illuminance," A new paradigm for assessing daylight in buildings, vol. 37, No. 1, pp. 41-57, 2015.

[22] M. Majdalani, "Sustainability in the construction industry: a Lebanese case study," Construction innovation, No. 6(1), pp. 33-46, 2006.

[nd] Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

COST COMPARISON OF CONCRETE FRAMED STRUCTURE USING NATURAL AND ARTIFICIAL COARSE AGGREGATES

Zeeshan Ullah[a]*, Engr. Shah Jahan[b], Engr. Sami Ullah[c], Engr. Muhammad Sarwar[d], Engr. Muhammad Irfan[e]
a: PhD student, Dept. of Construction Engineering & Management (CE&M), NIT, SCEE, NUST, Islamabad, Pakistan
zeshan880@gmail.com
b: Assistant Director, TEPA, LDA, samigondal.lda@gmail.com
c: Assistant Engineer, University of Jhang, ayyansarwar273@gmail.com
d: Assistant Professor, University of Lahore, Gujarat Campus, *Shahjahan1002@gmail.com*
e: Lab Engineer, Civil Engineering Department, KFUEIT Rahim Yar khan, *engr.mirfan1992@gmail.com*

Abstract: Due to increase in environmental issues, construction industry is continuously in search of materials that do not pose hazard to the environment. There is a need of cost effective and lightweight concrete mix that resolves these problems. This research provides solution to these problems alongside with significant compressive strength using naturally available lightweight structural aggregates concrete (LWSAC). Due to their low density they produce lightweight concrete, which also have better insulation property and brings down construction, operational and maintenance cost of the building. The aim of this study is to choose the best locally available material to produce lightweight concrete. Low density of these materials will lead to less dead load, hence reduced size of structural members which reduces overall construction cost. Low thermal conductivity leads to energy efficient housing. For this purpose, three samples will be taken. Low density means less dead load and hence reduced size of foundations, which reduces cost and concrete production. Low thermal conductivity leads to energy efficient housing. For this purpose, a sample was prepared using artificial (slate) aggregates from PCSIR Lab Peshawar as replacement for natural aggregates in concrete. Concrete samples were tested for strength, electrical conductivity, and thermal conductivity. These tests showed that, the particle size of artificial lightweight aggregates is larger than particle size of natural aggregates that will helpful in improving strength of concrete. Bulk density of artificial lightweight aggregates in loose state is only 70% of that of natural aggregates and similarly bulk density of artificial lightweight aggregates in compact state is around 68% of that of natural aggregates. Thermal conductivity of artificial lightweight aggregates concrete is 1.030 which is around 49% of that of normal concrete. The electrical conductivity of artificial lightweight aggregates is 0.141 which around 16% lesser than electrical conductivity of normal concrete. After that, these properties were used in design of multistory building to check any variation in the member sizes. It is noted that compressive strength of LWSAC is similar to normal concrete but this concrete has better insulation properties than that of normal concrete. Overall cost of structural members has also reduced when LWSAC was used instead of normal concrete.

Keywords: Energy Performance, Normal Concrete, Lightweight Concrete, Natural Aggregates, Artificial Lightweight Aggregates, Human Comfort

1 INTRODUCTION

The most influential material in construction is concrete and many natural resources are utilized for its production [1]. It has three major components that are cement, water, and aggregates. Physical properties of concrete like grade, moisture absorption, thermal conductivity etc. are directly related with aggregate's characteristics, which is used in concrete [2]. Main problem confronted by construction industry is dense concrete production resulting in increased dead load, transportation/ handling cost which lead to low productivity and more manpower. The primary aim of this project is to provide an efficient strength to weight ratio by production of LWSAC that reduces dead load and hence member sizes.

For sustainable construction, LWSAC has been chosen for production of lightweight concrete with 10%, 20%, 50% and 100% replacement with natural aggregates. The aim of this study is cost comparison of concrete framed commercial building using normal weight concrete (NWC) and LWSAC and also to choose the best locally available material to produce LWSAC which has required strength, lower cost, density, electrical resistivity, and thermal conductivity than NWC. Low density means less dead load and hence reduced size of foundations which reduces cost and concrete production. Low thermal conductivity leads to energy efficient housing energy efficient building thus causing money saving, longer life span of buildings and least maintenance and operation cost. Reducing this building energy consumption will prove significant in reducing environmental impact.

For this purpose, one sample was taken. This sample was made using artificial (slate) aggregates from PCSIR Lab Peshawar as replacement for natural aggregates in concrete. Concrete samples were tested for strength, thermal conductivity, and electrical resistivity. After that, these properties were used in design of multistory building to check any variation in the member sizes.

2 LITERATURE REVIEW

The future of this planet is a matter of concern. Environmental issues and how human communities affect ecosystem concerns have been part of human society from the beginning. Since deterioration of environmental conditions in many parts of world, sustainable development has become a recognized goal for human society. Therefore, humanity has to pay more attention to the environment [3]. For several years, LWSAC has been used productively for structural objectives. The research has presented that it can be possible to make lightweight concrete by using Lightweight Expanded Clay Aggregates (LECA) with 10 % silica fume which achieved 70.5 MPa compressive strength having 1,860 kg/m³ density [4]. Some studies have shown that LWSAC with 43.8 MPa 90 days' compressive strength and dry density 1,860 kg/m³ can be produced by using basalt-pumice as coarse aggregates [5]. Many studies have been carried out on the different aspects of artificial lightweight aggregates such as manufacturing of LWSAC [6], properties of artificial lightweight aggregates [7], comparison between NWC and LWSAC in concrete mixture [8]. But this study is focusing on cost comparison of framed concrete commercial building using NWC and LWSAC.

Manufacture of lightweight structural aggregates concrete (LWSAC) involves using of variety of lightweight aggregates. Lightweight structural aggregates concrete (LWSAC) fulfills to the standard, defined in [9] "it should have a least compressive strength of 17 MPa nearly equal to 2500 Psi at 28 days and it should have a dry density value ranging between 1120–1920 kg/m³". Those aggregates whose particle density is not greater than 2000 kg/m³ or loose bulk density is not greater than 1200 kg/m³ are termed as lightweight aggregates (LWA) [10]. LWA can exist naturally or can be made artificially using industrial processes [11]. The properties of the LWA like strength, thermal and acoustic insulation depend on type of aggregates used for its production, so consideration of aggregates properties is very important for manufacture of LWSAC. Most of countries now a days are manufacturing light weight expanded aggregates called light expandable clay aggregates (LECA), using some clay which can expand called bloated clay [12].

2.1 Effect Of Lightweight Aggregates On Properties Of Concrete

High porosity is main property of LWSAC, which results into low specific gravity. Strength of LWA particles depends on source and type of aggregates. The strength of concrete is not depending upon strength of coarse aggregates since there is no exact relationship between aggregates strength and concrete strength [13]. Generally, compressive strength of concrete is related to content of cement at a given particular slump instead of water to cement ratio (w/c) [14]. In some cases, compressive strength can be increased by using good quality natural sand in place of fine light weight aggregates [15]. The NWC aggregate zone is stronger in conventional concrete as compared to the interfacial transition zone (ITZ) and cement matrix. Contrary to that, introduction of artificial lightweight aggregates in concrete mixture significantly affects the mechanical and elastic properties of lightweight concrete, since they are the weakest constituents [16]. Literature tells that strength of concrete is determined by its weakest component. Transformation of stress takes place through aggregates and mortar. If aggregates are weak, then transformation of stresses occurs through cement matrix, resulting into cracks propagation throughout LWA particles. This suggest that LWA itself is weaker than interfacial transition zone (ITZ) [17]. Therefore, density and volume of constituent LWA is very important to get results comparable with NWC [18].

LWSAC is subjected to more creep and shrinkage as compared to equivalent NWC cylinder. Such factors should be considered during design purposes [19]. The significance of using light expandable clay aggregates (LECA) in concrete mix is better bond formation between mix constituents. The "Wall Effect" which is related to particle packing does not exist on surface of expanded clay aggregates in LWSAC by scanning electron microscopy (SEM) and back scattered electron imaging (BSEI), resulting in a better bond and much thinner interfacial zone than NWC [20]. Expandable LWA have better thermal resistivity and insulation as compared to NWC because of lower coefficient of thermal expansion, lower thermal conductivity, and fire stability. Since they are made by heating at very high temperatures of 2000^0F [21]. The lower thermal conductivity causes exposed members to achieve a steady state temperature at a higher time, thus decreasing the internal temperature changes. This time difference lag moderate nightly cooling effect and solar buildup in buildings. Such property of thermal resistivity can be useful in tall buildings where exposed lightweight columns have no large volume and stresses variations due to lower coefficient of thermal expansion [22].

3 RESEARCH METHODOLOGY

One of the main challenges in sustainable design of buildings is to improve the energy efficiency of the building during its lifetime along with reducing the environmental impact of the design. Concrete is the most widely used construction material in building industry and consumes second highest amount of natural resources [23]. In order to make concrete more environmentally sustainable, it should be energy efficient. Thermal conductivity is the most influencing factor in energy efficiency of concrete. Thermal conductivity of concrete is dependent on type of aggregates used in the concrete mixture. Some published construction properties databases associate thermal conductivity to concrete density. Therefore, it is possible to make concrete more energy efficient by replacing natural aggregates with low density LWA. The value of thermal conductivity of concrete is decreased by $0.13Wm^{-1}K^{-1}$ with the introduction of artificial lightweight aggregates in concrete and proven by the research work. Properties other than thermal conductivity were also studied and compared with NWC. After performing preliminary tests on NWC and LWSAC, properties of NWC and LWSAC has been used in design of commercial building. The cost analysis has performed for all the structures and hence cost comparison is carried out to find out the most economical structure out of these two.

3.1 Choice Of Aggregates

The choice of aggregates is very much related to a local supply chain. So, in this study we choose the best locally available aggregates to produce LWSAC which has required strength, minimum cost, low density, thermal conductivity and electrical resistivity. As the most important property, is its lightweight, which will result into decrease in dead load, thus enabling use of lightweight structures, reducing cost in handling and transportation, and enhancing labor productivity. Decrease in dimensions of structural members and good thermal and acoustic insulation can be achieved from its low density. Increased cost of LWSAC can be covered based on its ease in handling, less energy requirement in demolishing, less waste requirement and high durability due to strong bond of aggregates. After identification of properties, availability of artificial lightweight aggregates was located. Artificial lightweight aggregates were chosen for further research. Slate for this research was extracted from Manki Formation (95 km from Peshawar city). Manki Formation is characterized by metamorphic rocks from Precambrian age e.g. slate, quartzite and phyllite. Raw slate used was fine grained rock split into thin broad sheets with gray to black color. The slate is NWA but it is converted into a lightweight aggregate by expanding it. Slate may be prepared similarly to a non-bloating slate by reducing it to a fine powder, mixing it with a bloating agent and shaping [23]. LWA, expanded slate was yielded in PCSIR laboratory Peshawar through processing of natural aggregates in rotary kiln method. The chemical composition of shale Karachi is, 37-60% weight of $Si0_2$, 15-26% weight of $A1_2O_3 + Ti0_2$, 3-13% weight of Fe_20_3, 11-16% weight of alkaline earths (CaO+MgO) and alkalies (Na_20+K_20) and loss on ignition 3.94%. The chemical composition of shale Peshawar is, 59.07% weight of $Si0_2$, 0.57% weight of $A1_2O_3 +$ $Ti0_2$, 15.85% weight of Fe_20_3, 10.25% weight of alkaline earths (CaO+MgO) and alkalies (Na_20+K_20) and loss on ignition 3.87%.

3.2 Formulation Of Mix Design

Five formulations were designed. Following were the quantities for the respective mixes:

6. N100 (using 100% natural coarse aggregates)
7. N90 A10 (using 90% natural & 10% artificial coarse aggregates)
8. N80 A20 (using 80% natural & 20% artificial coarse aggregates)
9. N50 A50 (using 50% natural & 50% artificial coarse aggregates)
10. A100 (using 100% artificial coarse aggregates)

4 RESULTS AND DISCUSSIONS

4.1 Compressive And Splitting Tensile Strength Of Concrete

Six cylindrical samples (6"x12") for each artificial (10%, 20%, 50% & 100%) and natural (100%) aggregates were casted and tested at 07 and 28 days for compressive strength. In this method, cylinders were subjected under axial compressive load for some time until the sample fails. The maximum load, which was attained by sample before its failure, was divided by the sample cross section area to get compressive strength of sample. (ASTM C 39). Six cylindrical samples (6"x12") for each artificial (10%, 20%, 50% & 100%) and natural (100%) aggregates were casted and these samples were casted and tested at 07 and 28 days splitting tensile strength. Basically, in this method we were calculated indirect tensile strength of the concrete. (ASTM C 496/C 496M).

Test results for compressive strength are shown below in Fig-1. It is clear from figure that maximum compressive strength yielded by N100 having NWC altogether. But it is also interesting fact that all these samples have cleared the minimum threshold limit of compressive strength that is 2500 Psi. Which means that all these types of concrete can be used for construction purposes. It is also an interesting fact that compressive strength of concrete is decreasing with increase in percentage of LWA in concrete.

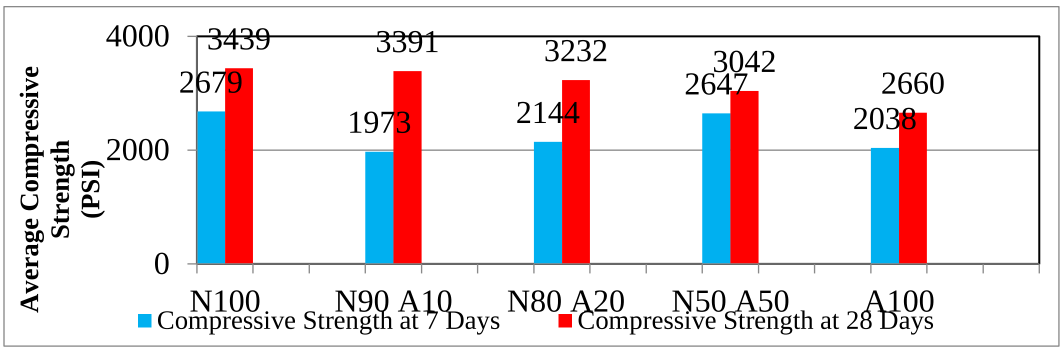


Figure 1: Compressive Strength at 7 & 28 days

Test results for splitting tensile strength are shown below in Fig-2. Almost similar tread has been noted here in split tensile strength. Where the strength of concrete is decreasing with increase in percentage of LWA in concrete. But all these samples have the strength more than the minimum threshold value. Hence all these types of concrete can be used in construction.

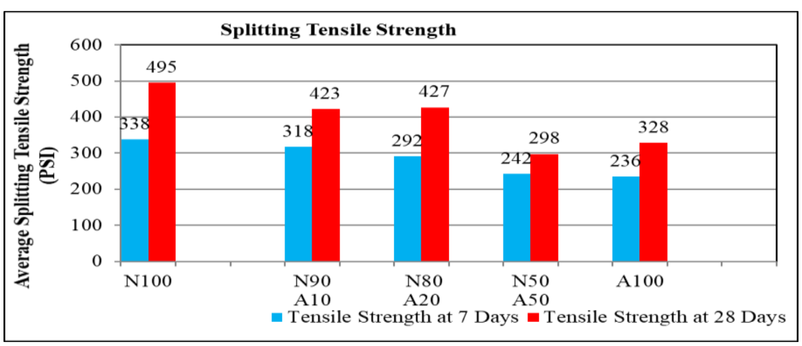


Figure 2: Splitting Tensile Strength at 7 & 28 Days

4.2 Thermal Conductivity And Electrical Conductivity

Tests results of thermal conductivity for NWC and LWSAC are shown in Fig-3 and Fig-4 respectively. NWC has the highest thermal conductivity and Slate has the lowest Thermal Conductivity. Lesser the thermal conductivity lesser will be heat passed through building hence results in reduction in energy consumed by building [23]. On basis of pairwise comparison putting their relative scores in software and graph extracted shows that Slate is the best alternative with respect to thermal conductivity.

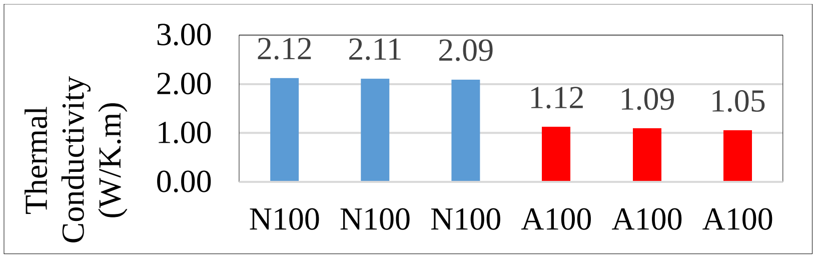


Figure.3: Thermal Conductivity

It is cleared that NWC has the highest Electrical Conductivity and Shale Karachi with 10% sawdust has the lowest electrical conductivity. On the basis of pairwise comparison putting their relative scores in the software and results obtained shows that Shale Karachi with 10% sawdust is best alternative with respect to Electrical Conductivity.

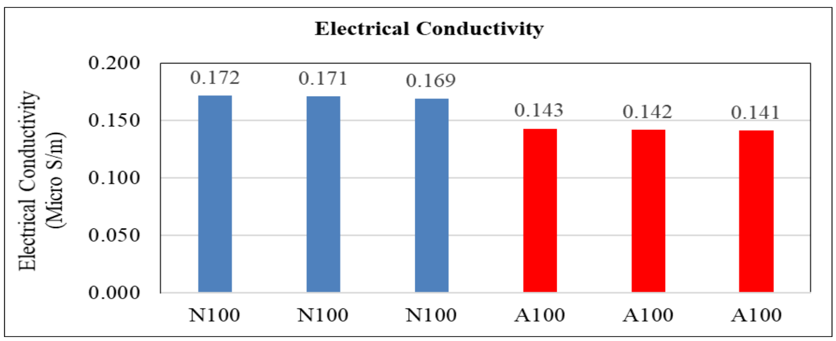


Figure 4: Electrical Conductivity

4.3 BUILDING DESIGN FOR COST COMPARISON

ETABS software was used to design triple stories buildings for all five formulations (N100, N90 A10, N80 A20, N50 A50 & A100) having plot size (150' x 60') according to the obtain results from our experimental work. Five buildings were design with different properties of concrete to investigate volumetric changes of members.

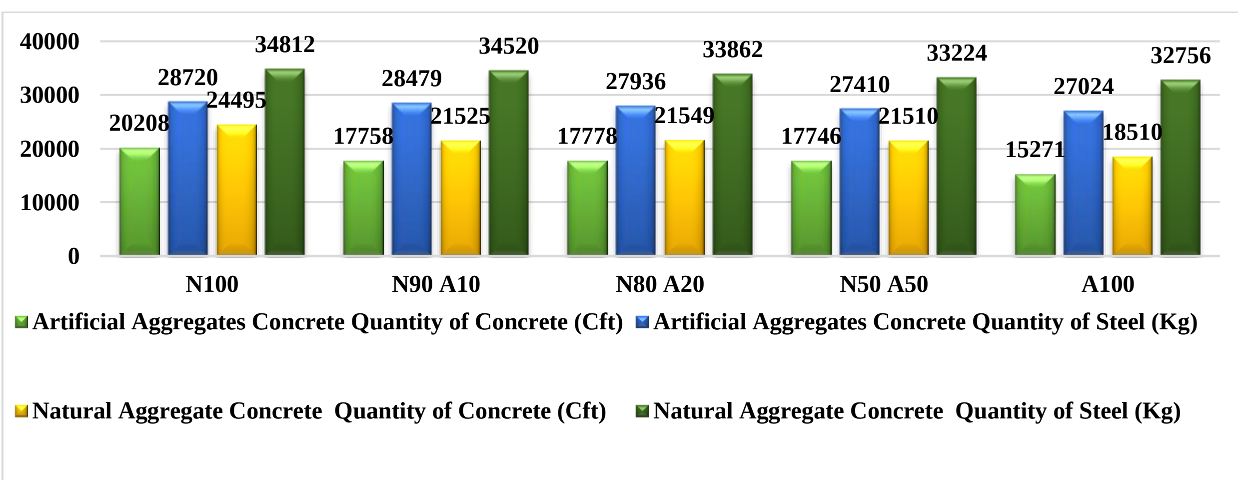


Figure 5: Cost Comparison of Building using Natural and Artificial Aggregates

The overall cost comparison of these buildings is given below in Fig-5. It is cleared from results that as LWA are increasing the member sizes are decreasing resulting in decrease in concrete quantity and hence cost of construction. Hence it can be concluded that even with the larger upfront cost of LWSAC due to more cost of LWA, even overall cost of building reduced with greater percentage which may balance upfront cost of LWSAC.

5 CONCLUSIONS AND RECOMMENDATIONS

In order to find out the effect of LWSAC on building performance and building demand, an attempt is made to evaluate effect of LWA on thermal and electrical performance and hence on building. Following are major findings of this project.

1. Bulk density of LWA in loose state is only 70% of that of NWA and similarly the bulk density of LWA in compact state is around 68% of that of NWA. This lesser density will reduce the self-weight of concrete and also self-weight of overall building. This reduction in self-weight of concrete and overall building will reduce the members' size and hence reduce the overall cost of building.
2. The specific gravity of LWA is only 1.88 which is 74% of that of NWA. This lesser specific gravity indicates lesser number of voids in concrete prepared with LWA as compare to concrete prepared with NWA.
3. Thermal conductivity of concrete prepared using LWA was coming out to be 1.030 which is around 49% of that of concrete prepared by using NWA. Lesser the thermal conductivity of material lesser will be heat transformation and moderate will be the room temperature. This moderate room temperature will reduce the energy demand of building and hence saves operational cost of building.
4. The electrical conductivity of concrete prepared by using LWA was 0.141 which around 16% lesser than the electrical conductivity of concrete prepared by using NWA. Lesser electrical conductivity of building better will be the comfort level of building.
5. The cost of LWA is very much higher than cost of NWA. It is because LWA are not producing in bulk amount that is why the manufacturing rate of small sample of LWA are larger than the cost of NWA. But though this higher cost of LWA will be compensated in energy saving and comfort level of building.

After the comprehensive test results and suitable findings following conclusions are made for the stake holders as well as for the future research.

1. Pakistan is suffering from energy crises that is why building should be constructed using artificial lightweight aggregates that will help in reducing energy demand of building and also improve building comfort level.
2. Partial replacement (50%) gives better compressive strength without plasticizers than 100% replacement of artificial lightweight aggregates but we can also use 100% replacement of artificial lightweight aggregates after improving compressive strength using plasticizers.
3. Life cycle costing and life cycle cost analysis should be carried out in future to find out variation in different phases and components of buildings.

REFERENCES

[1] Bakış, "Procedia - Social and Behavioral Sciences," Sustainability in Construction Sector, vol. 195, pp. 2253-2262, 2015.
[2] Bogas, "Compressive behavior and failure modes of structural lightweight aggregate concrete," Characterization and strength prediction. Materials & Design, p. 46, 2013.
[3] Claisse, "Chapter 19: Aggregates for Concrete and Mortar," in Civil Engineering Materials, 2016, pp. 177-188.
[4] Abul Bashar Emon, "Improving performance of light weight concrete with brick chips using low cost steel wire fiber," Construction and Building Materials, vol. 106, pp. 575-583, 2016.

[5] Petrullo, "Smart Market Report World Green Building Trends 2016: Developing Markets Accelerate Global Green Growth Smart Market Report.," 2017.
[6] Ramu, "Cost Comparison of Light Weight Aggregate Concrete by using Cinder," International Journal of Scientific Engineering and Research, vol. 4, No. 53, pp. 11473-11479, 2015.
[7] Tabassom Safikhani, "A review of energy characteristic of vertical greenery systems," Renewable and Sustainable Energy Reviews, vol. 40, pp. 450-462, 2014.
[8] V. Shami Nejadi, "Mix Design of Light-Weight Self Compacting Concrete," Case Studies in Construction Materials, vol. 4, pp. 1-14, 2016.
[9] Ch. Madhavi, "Electrical Conductivity of Concrete," ARPN Journal of Engineering and Applied Sciences, vol. 11, No. 1819-6608, 2016.
[10] Duran, "The Components of Sustainable Development-A Possible Approach," in Procedia Economics and Finance, 2015.
[11] Gravitt, "Eco-Efficient Construction and Building Materials," Constr. Manage., 2013.
[12] Mehrdad Massoud Nejad, "Investigating and Comparing the Economic Use of Normal Concrete and Lightweight Concrete in Iran," Journal of Current Research in Science, pp. 560-564, 2016.
[13] Katia Perini, "Vertical greening systems and the effect on air flow and temperature," Building and Environment, vol. 46, No. 11, pp. 2287-2294, 2011.
[14] K. Ding, "Sustainable construction—The role of environmental assessment tools," Journal of environmental management, pp. 86(3), 451-464, 2008.
[15] Ruveyda Komurlu, "Energy and Atmosphere Standards for Sustainable Design and," Energy and Buildings, Vol. 90, Pp. 156-165, 2015.
[16] J. Mohamed Muftah Mustafa, "Properties of Different Artificial Lightweight Aggregates and Their Effects on Concrete Strength," ARPN Journal of Engineering and Applied Sciences, vol. 11, No. 6, 2016.
[17] K. Erg¨ul YAS¸AR, "High Strength Lightweight Concrete Made with Ternary Mixtures," Turkish J. Eng. Env. Sci, vol. 28, p. 95 – 100, 2004.
[18] K. Mehdi Robati, "Incorporating Environmental Evaluation and Thermal Properties of Concrete Mix Designs. Construction and Building Materials," Construction and Building Materials, vol. 128, pp. 422-435, 2016.
[19] K. Norazila, An investigation on effect of quarry dust as sand replacement on compressive and flexural strength of foam concrete (Doctoral dissertation), Universiti Malaysia Pahang, 2010.
[20] L. Srinivasan.K, "An Experimental Study on Manufacturing of Artificial Aggregates Incorporating Fly ash, Rice Husk Ash and Iron Ore Dust," International Journal of Science, Engineering and Technology Research (IJSETR), vol. 5, No. 1, 2016.
[21] M. Ali Nobil Ahmad, "Useful daylight illuminance," A new paradigm for assessing daylight in buildings, vol. 37, No. 1, pp. 41-57, 2015.
[22] M. Majdalani, "Sustainability in the construction industry: a Lebanese case study," Construction innovation, No. 6(1), pp. 33-46, 2006.
[23] M. Sengul, "Effect of expanded perlite on the mechanical properties and thermal conductivity of lightweight concrete," Energy Build. pp 671-676., 2011.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

EXPLAINING SUCCESS IN GREEN BUILDING PROJECTS USING TRANSFORMATION-FLOW-VALUE-GENERATION THEORY

Tayyab Ahmad
Faculty of Architecture Building and Planning, the University of Melbourne, ahmadt@student.unimelb.edu.au

Abstract- Green Buildings (GBs) are construction projects developed on the principles of sustainable development. Project success in GBs is an important concept to determine their performance. This concept is operationalized by success factors which affect the performance of a GB project and success criteria based on which a project's performance can be determined. Previous studies on GBs are limited in providing an interpretation of the Success factors and Success criteria in terms of the theories related to construction. This lack of interpretation has constrained the development of theory as well as research on GB project success. With a focus towards Green Buildings, this paper aims to explore the use of the Transformation-Flow-Value-generation (TFV) theory for interpreting success factors and success criteria. Upon analysing a few examples of Success factors and criteria, it is realized that the TFV theory can interpret GB project success. The findings presented in this paper have theoretical implications as these can inform research in construction projects in general and GB projects in particular. For future research on GB project success, the TFV theory can be used as a theoretical framework.

Keywords- Green Building, Transformation-Flow-Value-generation theory, Waste, Success factors, Success criteria

1 INTRODUCTION

Building projects are associated with negative environmental effects and Green Buildings (GBs) can help reduce these. Since buildings fulfil the requirements of human life on a daily basis in terms of living and working, they are extremely important part of the built environment. However, services from buildings come at a cost as the building and construction sector tend to consume large amounts of resources. For instance, the buildings and construction sector in 2018 accounted for 39% of energy and process-related carbon dioxide (CO_2) emissions and 36% of final energy use [1]. To mitigate these environmental effects, Green Buildings have been proposed. Compared to traditional buildings, GBs have considerations towards socio-economic and environmental aspects, and this increases their market demand [2]. GB projects are becoming increasingly popular in society and this signifies the need for effective development practices regarding these projects.

1.1 Green Building project success

For theory and practice of GB development, the concept of GB project success has much importance. To conceptualise project success, it is necessary to answer two key questions: 'what' is project success and 'how' to achieve project success. Success criteria and Success factors are the answer to these questions. Success criteria help conceptualise 'what' project success is. These are the principles or standards by which project performance can be evaluated. For instance, quality performance is a criterion on which project performance is determined. Once Success criteria applicable to a certain project type are determined, it is possible to conduct intermediate or post-completion audits to identify the reasons for project success or failure. Based on the acquired knowledge, remedial actions can be taken for a project or the learnt lessons can be applied to future projects [3]. Success factors help conceptualise 'how' project success is achieved. These are circumstances, facts, or influences to facilitate or impede project success [4]. For instance, project team collaboration facilitates project success and is, therefore, a Success factor. If success enabling conditions are ignored during the project development, a multitude of problems can result, and project performance may be detrimentally affected. Similar to any other project, success of GB projects can be conceptualised using success factors and success criteria.

Success criteria in case of GB projects include Project Management-related criteria such as Schedule, Cost, and Quality Performance [5-10]. Since GB projects are developed on sustainable development principles their success criteria also include: Environmental sustainability performance (such as water consumption, energy consumption, and consumption of resources and materials) [5, 9-14]; Economic sustainability performance (such as life cycle cost and business performance) [5, 6, 11]; Social sustainability performance (such as indoor environmental quality, owner and end-users' satisfaction, acoustic quality, and thermal comfort) [5, 9, 10, 12]; and performance in Green certifications [7-10, 15]. The factors enabling success (i.e. success factors) in GB projects include effective team communication, commitment of all project participants, support from senior management, skillfulness of project participants, and early involvement of key project participants in GB development [10, 16].

1.2 Research gap and significance

Previous studies have identified Success factors and criteria of GB projects. Besides the identification of factors and criteria, it is also important to rationalize and explain the significance of Success factors and criteria for GB projects. This is possible if a relevant theory is used to interpret Success factors and criteria. Previous studies are limited in explaining the Success factors and criteria in terms of the theories related to construction. This lack of interpretation has constrained the development of theory as well as research on GB project success. For instance, 'Reducing environmental impact of construction' is a success criterion and 'effective team communication' is a success factor. A theory needs to explain the importance of such success factors and criteria for a GB project. Since GBs are essentially construction projects, their Success factors and criteria can be interpreted by a theory developed for or related to the construction industry.

Theories are formulated to predict, explain, and understand phenomena [17]. Theoretical framework is a structure that holds or supports a theory of a research study. A theoretical framework describes the theory which explains why the research problem under study exists. Previous studies on GB project success are limited in the use of theoretical frameworks for interpretation of findings and this has constrained the understanding and explanation of Success factors and criteria. Transformation-Flow-Value-generation (TFV) theory developed to explain construction projects can explain the development of GB projects. Based on this theory, the development process of a GB project can be defined in terms of Transformation (that is the transformation of inputs into outputs), Flow (that is the flow of materials involving transformation, inspection, moving and waiting), and Value-generation (that is value creation for the customer). With a focus on Green Buildings, this paper aims to explore the TFV theory as a theoretical framework for interpreting Success factors and Success criteria. In this paper, first the TFV theory of production is explained which is followed by the interpretation of GB success factors and criteria using the TFV theory.

2 TFV THEORY OF PRODUCTION

For construction projects, Koskela [18] found that the mismatch between the observed reality and conceptual models underscored the lack of robustness in existing theories. While realising the need for a theory of production in construction, Koskela developed an overarching production management paradigm for construction projects. In developing this theory Koskela used the ideal production system embodied in the Toyota Production System. Koskela's understanding of construction was founded in the same ideas as that for manufacturing, where the nature of the production was seen from three viewpoints: as a flow of work, as a chain of transformations, and as a generation of value for the customer. Upon identifying these viewpoints, Koskela used them to explain the construction process. The TFV theory of production in construction proposed by Koskela can explain the development of GB projects and interpret Success factors and criteria for GB projects.

The three concepts or views (i.e. Transformation, Flow, Value-generation) encompassed in the TFV theory are not competing or alternative theories, but rather partial and complementary. Each view in the TFV theory has certain assumptions, principles, and contributions as shown in Table 1. Each of these views addresses certain aspects of the production phenomenon [18]. The development of a construction project can be conceptualised by collectively considering these three views and their associated principles as an integrated theory of production. For a research inquiry of project success, the significance of the TFV theory is that it explains how the goals of production in a construction project can be achieved. While the goal of getting the intended products ready is realised by task management, the goals of production related to external customer are achieved by value management.

Table 1: Integrated TFV view on production (Source: Koskela [18])

	Transformation view	**Flow view**	**Value-generation view**
Conceptualisation of production/ Assumptions	As a process in which inputs are transformed into outputs	As a flow of materials, composed of transformation, moving, waiting, and inspection	As a process where value for the customer is created by fulfilling his/her requirements
Main principles	Getting production achieved efficiently	Elimination of waste (non-value-adding activities)	Eliminating value loss (achieved value in relation to the best possible value)
Practical contribution	Taking care of what has to be done	What is unnecessary is done as little as possible	Ensuring the fulfilment of customer requirements in the best possible manner

The Transformation, Flow, and Value-generation views can interpret Success factors and criteria of GB projects. As compared to the existing theories, a much wider framework is provided by the TFV theory of production, since it provides the flexibility to perceive construction projects collectively from three viewpoints instead of only one viewpoint. Some Success factors and criteria may associate with all three views, some associate with two views, while the rest associate with one of the three views. Since Success criteria are directly and indirectly related to meeting project stakeholders' expectations, Value-generation view in the TFV theory, which explains the value created for project stakeholders, is particularly relevant in interpreting Success criteria. GB Success factors which result in eliminating or reducing non-value adding activities may be interpreted using the Flow view. Success factors which help realise the efficient development of a project may be interpreted using the Transformation view. Success factors which are about the elimination of value loss can be interpreted using the Value-generation view. Hence, the three views within the TFV theory can provide the theoretical interpretation of GB Success factors and criteria.

2.1 Green Building development from the Transformation view

According to the Transformation view in the TFV theory, GB project development can be considered as a transformation of labour, information, equipment and materials into a sustainable building. The intellectual origins of Transformation view are in economics, where it remains unchallenged to this day [19]. The Transformation view of production has remained dominant throughout the twentieth century. According to this view, production is about transforming inputs into outputs [18]. Production management in this viewpoint equates to decomposing the total transformation into elementary transformations and tasks, acquiring the inputs to these tasks with minimal costs, and executing the tasks as efficiently as possible [18].

The main principle of transformation is to get production achieved efficiently [18]. Principles of production in transformation suggest hierarchically decomposing the total transformation into smaller transformations (that is tasks), and minimising the cost of each task independent of the others. The Transformation view has much importance in discovering the tasks needed in a production undertaking and in achieving those tasks [19]. For instance, planning GB project development is an aspect strongly associated with the Transformation view. This is because project planning involves breaking the overall transformation (i.e. project) into a number of component transformations (i.e. activities) which are individually optimised for cost, time, and resources.

There are two main deficiencies related to the Transformation view of production: first, it does not recognise the phenomena in production other than transformations, and second, it fails to recognise that it is not the transformation itself that makes the output valuable, but, instead, the value is a result of output conforming to the customer requirements. The issue of avoiding the waste of resources and meeting customer requirements are not addressed well by the Transformation view and these aspects are explained by the Flow and Value-generation view respectively [19].

2.2 Green Building development from the Flow view

In the Flow view, the GB project development is a flow of resources (such as people, material, and information) to result in a sustainable building. The early framework of industrial engineering introduced production in terms of the Flow view. The Flow view of production, first described in scientific terms by Gilbreth and Gilbreth [20], has provided the basis for Just-In-Time and lean production. According to the Flow view, production is a flow of materials involving transformation, inspection, moving and waiting [18]. Flow can be defined as "movement that is smooth and uninterrupted, as in the 'flow of work from one crew to the next' or the flow of value at the Pull of the customer." The basic thrust in the Flow view is to eliminate waste from the flow processes, promoting such principles as variability reduction, lead-time reduction, and simplification [19]. The main principle of the Flow view is the elimination of waste, that is non-value-adding activities. The triumph of Just-In-Time and lean production based on the Flow view has practically proven the power of this concept [18].

GB Success factors such as 'effective team communication' can be well interpreted by the Flow view. This is because these Success factors help reduce non-value-adding activities and strongly influence project development in terms of the flow of materials, resources, and labour. Even though the Flow view explains how to avoid waste, it does not particularly address the issue of meeting customer needs. The Value-generation view considers this aspect to explain project development.

2.3 Green Building development from the Value-generation view

The GB project development, according to the Value-generation view, is a process of producing a sustainable building which meets the client's requirements. The view of production as Value-generation was articulated in the 1930s with the basic goal of achieving the best possible value for the customer [19]. Production management according to the Value-generation view is to accurately translate customer needs into a design solution, and then developing products which conform to the specified design [18]. Value can be about the usefulness, functionality, utility, and benefit of a product. According to this view, the ultimate goal of the production process is the intended use of a product by the customer. Value for the customer is, therefore, the dominant value perspective in the TFV production theory by Koskela. Within this tradition, the definition of value can, therefore, be specified as an output of production required by the customer [21]. The main principle of the Value-generation view is to eliminate the value loss, that is reducing the gap between the achieved value and the best possible value [18].

GB Success factors such as those related to defining project goals and project design development can be well interpreted by the Value-generation view. This is because these Success factors are about capturing project requirements, converting these requirements into a workable plan (that is design), and therefore creating value for the project client. Moreover, the Value-generation view is also well-suited to interpret GB Success criteria. This is because most of the GB Success criteria such as achieving green certifications are about meeting the requirements of the project client or creating value for the client.

In high-performance buildings, the environment is elevated to be a key stakeholder of the building alongside that of the customer (that is building owner or user) [22]. Conventional projects set objectives for the building owner and user, but rarely address the needs of the environment explicitly. The disclosure of environmental objectives required in case of high-performance buildings makes those activities critical that were otherwise thought as marginal (that is wasteful), for example, energy modelling and life-cycle cost analysis [23]. Hence, by acknowledging the environment as a stakeholder in the Value-generation view, the TFV theory can explain why the particular steps taken and activities performed in GBs are important for the success of these projects. While the Transformation, Flow, and Value-generation views in the TFV theory can explain GB project success, the concept of waste defined by the TFV theory can also explain GB Success factors and criteria.

2.4 Waste defined by the Transformation, Flow, and Value-generation view

According to the TFV theory, in a GB project waste is the loss of materials, time, or value during project development. The Waste concept can be embedded in the TFV theory to provide an enriched interpretation of the Transformation, Flow, and Value-generation view. Waste (loss of material, time, or value) is an important aspect for interpreting GB project success because of two reasons. First, waste in the project development process reduces the potential of successfully achieving project outcomes, an aspect directly related to project success. Second, waste in the end-product and the production process is in direct contrast with sustainability goals, an aspect related to sustainable development. The TFV framework helps conceptualise waste in the process of project development and the waste related to the end-product (such as building project). All three views of the TFV theory (that is Transformation, Flow and Value-generation) are important for developing a comprehensive understanding of waste. In this paper, waste is not considered as a separate theoretical construct but as a concept strongly embedded in the TFV construct. Alongside the principles of Transformation, Flow and Value-generation, the waste definitions by the TFV theory can also be used in interpreting GB Success factors and criteria as shown in Figure 1.

In the Value-generation view, waste implies value loss, for instance, a situation where the product is not used as intended. Waste according to this view also means that "part of value (is) not provided even if potentially possible" [18]. According to Womack and Jones [24] waste also means the delivery of a wrong product or service. The concept of value loss can be adopted to refer to the part of value not provided even if potentially possible. This concept can also be used to measure value in relative terms [18]. When analysing value, Rooke, et al. [25] distinguished outputs from outcomes. Based on this distinction it can be said that in the Value-generation view, waste is a situation where the outputs of production do not equate to outcomes [21]. This can be because the product does not meet the client's requirements, could have met the requirements in a better way, or is not used as intended. These are the reasons related to a product coming out of production; however, the unwanted outcomes are not limited to the (main) product, they also include unwanted by-products of the production process. While the wastes related to the main product are in terms of the lack of quality (including defective product) and the lack of intended use, the waste related to by-products can be injuries, harmful emissions, and work-related sickness [21].

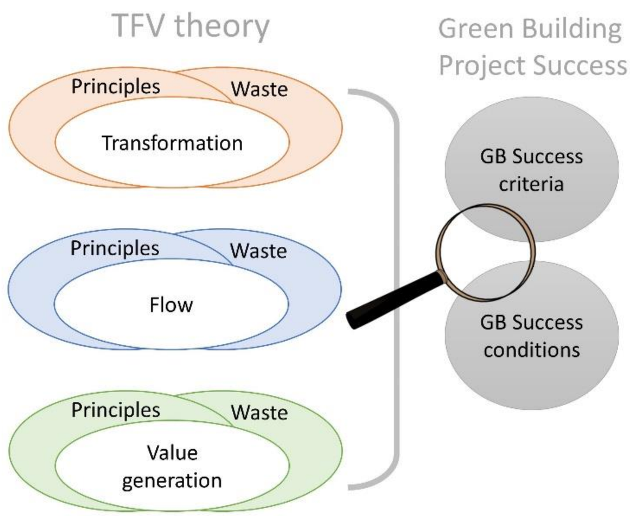


Figure 1: Interpretation of Success factors and criteria by the principles and waste definitions related to the Transformation, Flow, and Value-generation views

When considering the Transformation view, production can be seen as the conversion of component parts and raw materials into products using machinery, labour and energy. Waste in this view implies the use of more production resources than needed [21]. The Flow view recognises non-value adding activities in a project as waste [18]. Waste is the expense of labouring force which does not produce value [26].

Table 2: Taxonomy of the Wastes of production in construction (Source: Bølviken, et al. [21])

	Transformation	**Flow**	**Value**
Production resource	Machinery, materials, energy, and labour	Time	
Type of waste	Material loss	Time loss	Value loss
Wastes	Material waste Non-optimal material use Non-optimal use of machinery, energy, and labour	*In the workflow* Unnecessary work Waiting Unnecessary movement of people Inefficient work *In the product flow* Space not being used for work Unnecessary material transportation Materials not being processed	*Main product* Lack of intended use Lack of quality *By-product* Harmful emissions Injuries and work-related sickness

Ohno [27] identified seven sources of waste. Among these, the five sources refer to the flow of material, including (1) the waste of overproduction, (2) the waste of correction, (3) the waste of material movement, (4) the waste of processing, and

(5) the waste of inventory. Two waste sources referring to work of men are also identified and these are the waste of waiting, and the waste of motion. Bølviken, et al. [21] realised that the classical list of wastes provided by Ohno was context-specific (that is related to mass production) and a list specific to construction was required. A taxonomy related to the waste of production in construction was provided based within the TFV framework (Table 2).

3 INTERPRETATION OF GREEN BUILDING PROJECT SUCCESS

This section provides the interpretation of GB Success factors and criteria using the principles and Waste concept related to the TFV theory. The potential of the TFV theory to interpret GB Success is shown by a few examples of Success factors and criteria in Table 3.

Table 3: Interpretation of Green Building Success factors and criteria in terms of the TFV theory

		Can be interpreted in terms of …				**The condition/criterion can be associated with the Waste concept since it prevents…**	**Why related to TFV principles or Waste concept**
		T	**F**	**V**	**W**		
Success criterion	Reducing environmental impact of construction	×			×	Material loss	*Interpretation by Transformation view*: Fulfilling this criterion means that there is an efficient transformation of inputs into outputs.
	Achieving Green certifications			×	×	Material loss	*Interpretation by Value-generation view*: Fulfilling this criterion means that the client's aspiration of Green certification is met. Hence, value is created.
Success factor	Effective team communication		×	×	×	Material loss. Time loss	*Interpretation by Flow view*: This condition reduces the various non-value adding activities associated with the lack of project information. *Interpretation by Value-generation view*: This condition reduces the risk of not meeting project requirements hence contributing towards the value for project client.
	Early involvement of project team		×	×	×	Material loss. Time loss	*Interpretation by Value-generation view*: As a result of this condition possibility of meeting project requirements increases hence contributing towards the value for project client. *Interpretation by Flow view*: Project information available for decision-making because of early team involvement leads to effective decision-making reducing non-value adding activities. associated with the lack of project information.

***Note**: T=Transformation view; F=Flow view; V=Value-generation view; W=Waste concept*

GB Success criteria can be interpreted using the principles and Waste concept related to the TFV theory. Some of the Success criteria related to GB projects include achieving Green certifications [15] and reducing the environmental impact of construction [5, 14]. The interpretation of these Success criteria in terms of the TFV theory (shown in Table 3) is as follows,

- 'Reducing environmental impact of construction' is a criterion strongly associated with the concept of Waste reduction. Reduction in greenhouse gas emissions, embodied energy, waste, and water usage means that the waste of resources occurring in the development and operation of a building is reduced. Since this criterion is also about preventing material waste during construction, fulfilling this criterion means that there is an efficient transformation of inputs (that is construction materials) into outputs (that is building).
- Achieving Green certifications is a criterion associated with both the Value-generation and the Waste reduction concept. Since GB certifications can lead to sustainable project development these criteria add value for a client. Green certification of GB projects (such as Leadership in Energy and Environmental Design (LEED) certification) is the desired outcome for many clients. The energy waste is also reduced because of Green certifications since for fulfilling certification requirements the building performance is optimised and the environmental footprint of construction is reduced.

Some of the Success factors related to GB projects include effective team communication and early involvement of key project participants (that is project team) in GB development [16]. The interpretation of these Success factors in terms of the TFV theory (shown in Table 3) is as follows,

- 'Effective team communication' implies a smooth flow of information among the project team and across project stages. This can reduce the various non-value adding activities (for example, inefficient design and construction) associated with the lack of information. Moreover, smooth information flow also reduces the risk of not meeting project requirements hence contributing towards value for the client. Because of effective communication, the risk of rework in the project (such as redesign and rework on construction site) is mitigated and hence the material and time-related wastes are prevented.
- 'Early involvement of project team' implies that different parties with relevant expertise in project development are available during the decision-making process. This means that well-informed decisions regarding project development can be made. This increases the possibility of meeting project requirements, therefore, easing the generation of the project value. By virtue of early project team involvement, opportunities for a more efficient development (for example, reduced labour, cost, and material resources) are created, therefore reducing the non-value adding activities (for example, redesign of the project, and rework on construction site).

The above-mentioned examples demonstrate that the principles of the TFV theory and the Waste concept based in the TFV theory have much relevance in providing a theoretical interpretation of GB Success factors and criteria.

4 CONCLUSION

For developing research in GB project success, a construction-related theory needs to interpret GB Success factors and criteria. The contribution of this paper is that it explores the potential of the TFV theory to interpret Success factors and criteria of GB projects. Upon analysis of few examples of Success factors and criteria, it is realized that the principles of Transformation, Flow, and Value-generation, and the concept of waste defined by the TFV theory can interpret GB Success factors and criteria. The findings presented in this paper have theoretical implications as these can inform research in construction projects in general and GB projects in particular. In practical terms, the better understanding of project teams and clients regarding GB Success factors and criteria, by virtue of the theoretical framework proposed in this study, will lead to better performance in GB projects. For future research on GB project success, the TFV theory can be used as a theoretical framework. Future research on construction projects other than GB projects can also explore the relevance of the TFV theory in explaining project success.

REFERENCES

[1] IEA, "Global Status Report for Buildings and Construction 2019," IEA, Paris 2019. [Online]. Available: https://www.iea.org/reports/global-status-report-for-buildings-and-construction-2019

[2] M. Petrullo, S. Jones, B. Morton, and A. Lorenz, "World green building trends 2018–Smart market report," *Dodge Data & Analytics*, 2018. [Online]. Available: https://www.worldgbc.org/sites/default/files/World%20Green%20Building%20Trends%202018%20SMR%20FINAL%2010-11.pdf.

[3] A. De Wit, "Measurement of project success," *International journal of project management*, vol. 6, no. 3, pp. 164-170, 1988.

[4] C. Lim and M. Z. Mohamed, "Criteria of project success: an exploratory re-examination," *International journal of project management*, vol. 17, no. 4, pp. 243-248, 1999.

[5] T. Ahmad, A. A. Aibinu, A. Stephan, and A. P. Chan, "Investigating associations among performance criteria in Green Building projects," (in English), *Journal of Cleaner Production*, vol. 232, pp. 1348-1370, Sep 20 2019, doi: 10.1016/j.jclepro.2019.06.013.

[6] M. El Asmar, A. S. Hanna, and W.-Y. Loh, "Quantifying performance for the integrated project delivery system as compared to established delivery systems," *Journal of Construction Engineering and Management*, vol. 139, no. 11, p. 04013012, 2013, doi: 10.1061/(ASCE)CO.1943-7862.0000744.

[7] E. Enache-Pommer and M. Horman, "Key processes in the building delivery of green hospitals," in *Proceeding from the Construction Research Congress*, 2009, 2009.

[8] N. M. Hanks, "Investigation into the effects of project delivery methods on LEED targets," MSc Thesis, University of San Francisco, San Francisco, California, 2015. [Online]. Available: http://repository.usfca.edu/cgi/viewcontent.cgi?article=1152&context=capstone

[9] A. O. Olanipekun, B. Xia, C. Hon, and A. Darko, "Effect of Motivation and Owner Commitment on the Delivery Performance of Green Building Projects," (in English), *Journal of Management in Engineering*, Article vol. 34, no. 1, Jan 2018, Art no. 04017039, doi: 10.1061/(ASCE)ME.1943-5479.0000559.

[10] S. Korkmaz, "Piloting evaluation metrics for high performance green building project delivery," Doctoral dissertation, 2007. [Online]. Available: https://etda.libraries.psu.edu/catalog/8089

[11] T. Yu, Q. Shi, J. Zuo, and R. Chen, "Critical factors for implementing sustainable construction practice in HOPSCA projects: A case study in China," *Sustainable cities and society*, vol. 37, pp. 93-103, 2018.

[12] V. Venkataraman and J. C. Cheng, "Critical success and failure factors for managing green building projects," *Journal of Architectural Engineering*, vol. 24, no. 4, p. 04018025, 2018.

[13] M. M. Bilec, "Investigation of the relationship between green design and project delivery methods," Lawrence Berkeley National Laboratory, 2008. [Online]. Available: https://www.osti.gov/servlets/purl/937581

[14] P. Sang, J. Liu, L. Zhang, L. Zheng, H. Yao, and Y. Wang, "Effects of project manager competency on green construction performance: the Chinese context," (in English), *Sustainability*, vol. 10, no. 10, p. 3406, Oct 2018, doi: 10.3390/su10103406.

[15] D. S. Carpenter, "Effects of Contract Delivery Method on the LEED (trademark) Score of US Navy Military Construction Projects (Fiscal Years 2004-2006)," Monterey, California. Naval Postgraduate School, 2005.

[16] V. Venkataraman and J. C. P. Cheng, "Critical Success and Failure Factors for Managing Green Building Projects," (in English), *J Archit Eng*, Article vol. 24, no. 4, Dec 2018, Art no. 04018025, doi: 10.1061/(ASCE)AE.1943-5568.0000327.

[17] G. Abend, "The meaning of 'theory'," *Sociological theory*, vol. 26, no. 2, pp. 173-199, 2008.

[18] L. Koskela, "An exploration towards a production theory and its application to construction," PhD Dessertation, VTT Technical Research Centre of Finland, Helsinki University of Technology, 2000.

[19] L. Koskela, G. Howell, G. Ballard, and I. Tommelein, "The foundations of lean construction," in *Design and construction: Building in value*, vol. 291, 2002, pp. 211-226.

[20] F. B. Gilbreth and L. M. Gilbreth, "Process charts and their place in management," *Transactions of the American Society of Mechanical Engineers*, pp. 38–41, 1922.

[21] T. Bølviken, J. Rooke, and L. Koskela, "The Wastes of production in construction – A TFV based taxonomy," in *22nd Ann. Conf. of the Int'l Group for Lean Construction*, Oslo, Norway, 25-27 June 2014, pp. 23-27.

[22] A. Lapinski, M. Herman, and D. Riley, "Delivering sustainability: Lean principles for green projects," in *Construction Research Congress 2005: Broadening Perspectives-Proceedings of the Congress*, 2005, pp. 53-62.

[23] M. J. Horman *et al.*, "Delivering green buildings: Process improvements for sustainable construction," (in English), *Journal of Green Building*, vol. 1, no. 1, pp. 123-140, Win 2006, doi: 10.3992/jgb.1.1.123.

[24] J. P. Womack and D. T. Jones, "Lean Thinking," *Simon and Schuster, New York*, 1996.

[25] J. Rooke, S. Sapountzis, L. Koskela, R. Codinhoto, and M. Kagioglou, "Lean knowledge management: The problem of value," *Proceedings IGLC-18*, July 2010 2010, doi: 10.3763/aedm.2008.S707.

[26] L. Koskela, R. Sacks, and J. Rooke, "A brief history of the concept of waste in production," 2012.

[27] T. Ohno, *Toyota production system: beyond large-scale production*. Portland, Oregon: Productivity Press, 1988.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

APPLYING SEMI DISTRIBUTION HYDROLOGICAL MODEL TO ASSESS HYDROLOGICAL REGIME IN LAI GIANG CATCHMENT, BINH DINH PROVINCE, VIETNAM

[a] Zeeshan Ahmed, [b] Thanh Nhan Duc Tran, [c] Quang Binh Nguyen
a: Water Resources and Glaciology Department, Global Change Impact Studies Centre (GCISC)
zeeshanahmed44@outlook.com
b, c: Water Resources Department, University of Science and Technology - The University of Danang
duc.dut.wr@gmail.com

Abstract- The discharge of water is considered as one of the most significant hydrological parameters as it defines the stream course, size, and shape. The information related to flood forecasting and prediction of sediment load can be thus obtained from observing flow discharge. The present study is carried out to determine the effects of various factors including climatic circumstances, topography, land use, type of soil on the water discharge in Lai Giang River Basin, Vietnam by using Geographic Information System (GIS), and semi distribution hydrological model (SWAT). In this process, GIS supplies spatial input files for the SWAT model set up and calibration. The simulation of water discharge in Lai Giang river basin was carried out between the years 1995-2009, has shown comparatively good results because R^2 and E values were above 0.7.

Keywords- Flood Forecasting, GIS, SWAT, Sediment Load.

1 INTRODUCTION

One of the main factors affecting the water discharge and sediment load is land use & land cover (LULC), these factors are playing a vital role of water discharge change in flow regime [1] [2] [3]. In Vietnam, form mid of the 1980s, the Government has started series of economic reforms, which means that their aim is to re-define the allocation of land use to enhance the development of economy, that results in the most remarkable policy named: "New Economic Zones program" [4]. Indeed, this policy displaced many living areas by uninhabited areas to expand the agricultural areas. This action led to the conversion of LULC in Vietnam for the period after the 1980s [5].

Water discharge is basically defined as the volumetric flow of water moving through a given cross-section of an area over a set time period [6]. The discharge of water is considered as one of the substantial hydrological parameters, for the fact that it defines the stream course, size, and its shape [7]. The outcomes obtained from monitoring water discharge could be valuable for flood forecasting and predicting sediment load [8]. Currently, along with the development of GIS, there are many techniques that can be helpful to calculate water discharge, precisely and fast, as compared to other old fashioned measurement methods [9]. The development of SWAT (Soil and Water Assessment Tool) model is one of the best ways to solve research related to LULC and it is becoming the most effective method nowadays. It is a small watershed to river basin-scale model which enables to enhance the accuracy of the simulated end result of water discharge from physical parameters of the basin and rainfall data. The model uses spatial input files for model setup and calibration to simulate different physical processes in the basin. In this model, a watershed is separated into many sub-watersheds. Similarly, an individual sub-watershed is divided further into unique soil/land-use characteristics called as hydrologic response units (HRUs). Moreover, through HRUs data in sub-watershed, the information related to the flow generation, sediments, and non-point source loadings can be obtained [10].

The Lai Giang river is one of the biggest rivers in the Binh Dinh Province. It formed from the merger of two rivers, An Lao river, and Kim Son river. The An Lao river and Kim Son river meets at the border area between Hoai An and Hoai Nhon districts in order to merge into the Lai Giang river. The Lai Giang River is flowing in the Southwest - Northeast direction, its height is about 400 - 825m. The overall area of the Lai Giang river basin is 1,269 km² approximately and the average height of its basin is approximately 300 m with the average slope is less than 0.25 degrees (Figure 1).

Previously, there were not many studies undertaken that assess the hydrological system of this study area due to a lack of data. This research aims to use the combination of remote sensing and observed data along with the semi distribution hydrological SWAT to figure out the change of LULC. Besides, this paper would hope to gain deeper insight into the change in river flow and sediment load at Lai Giang catchment, that plays an important role in Binh Dinh province, Vietnam. Due to the lack of observed data in central Vietnam, this study could be a leading study that can be applied to similar areas of Vietnam.

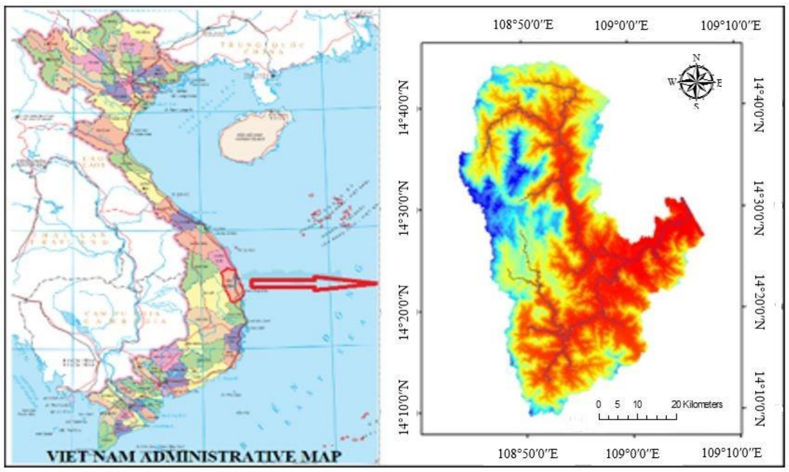


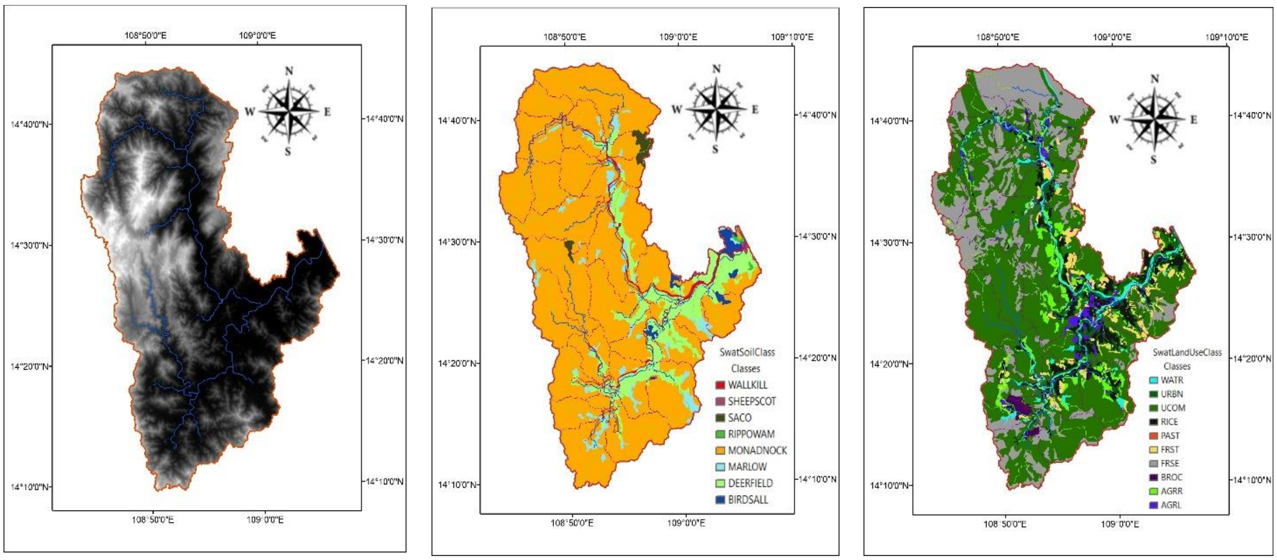
Figure 1: Lai Giang river basin in Central Vietnam

2 MATERIAL AND METHODS

For this survey, overall, 10 factors were considered for data input which included soil type, wind speed, Digital Elevation Model (DEM), rainfall, Land use, relative humidity, solar radiation, temperature, discharge, and sediment discharge. This paradigm is calibrated and validated on the basis of the data observed at An Lao station over years (1995-2009).

For the purpose of outlining sub-basins for the area under observation, an elevation model with 90 m resolution (DEM) was used which is available at National Map Seamless Data Distribution System (USGS) [11]. An elevation map (Figure 2a) was acquired by relying on the DEM. Landsat 8 OLI images (from 15 September 1990), with 30 m resolution, were used to generate a land use map (Figure 2b). For the ease, of interpretation and transformation of modifying the image, an enhancement process for refining (number) of images including multi-channel data combination was also taken into account for the creation of a new image. By using the probability of parameters and the most likelihood functions i.e. Maximum Likelihood method was used to carry out the image classification using ENVI 4.5 software. Consequently, 11 classes, with the inclusive accuracy of 90 %, were determined from the land use map: Water (WATR), Commercial (UCOM), Forest-Evergreen (FRSE), Residential (URBN), Pasture (PAST), Rice (RICE), Agricultural Land-Generic (AGRL), Broccoli (BROC), Agricultural Land-Row Crops (AGRR), Forest-mixed (FRST). For this survey, the soil type map, with a scale of 1:848,982 (Figure 2c) was extracted from National Pedology map.

The Center for Hydro-Meteorological Information and Data under the Vietnam Hydrometeorological Service (VHMS) of MONRE (Vietnam) provided the climatic data for the period of 1995-2009 which was available at 11 meteorological stations: Hoai An, Vinh Kim, An Lao, Vinh Son, Bong Son, Sa Huynh, Ba to, Duc Pho, Phu My, Gia Vuc, and Hoai Nhon. The climatic data used in this study included: daily wind speed (m/s), daily air temperature (maximum, minimum) (°C); daily relative humidity (%); daily solar radiation (MJ/m^2/day); and average rainfall (mm). Microsoft Excel was used to process every factor and after that, for the SWAT model, it was converted to pdf format. Apart from all this, some factors mainly; humidity, sunshine (number of hours), temperature and windspeed were used to obtain solar radiation by observing the max and min of the factors mentioned.



a. b. c.

Figure 2: Maps of Lai Giang River basin, a) DEM, b) Land use, and c) Soil types

The yearly average of sediment load (ton/day) for the period 1995-2009 was collected from An Lao hydrological station (Table 1). The methodology used in this study is shown in Figure 3.

Table 1-The average of sediment-load per year at An Lao station

Station	**The yearly average (ton/day)**	
	Min	Max
An Lao	3.5	113.79

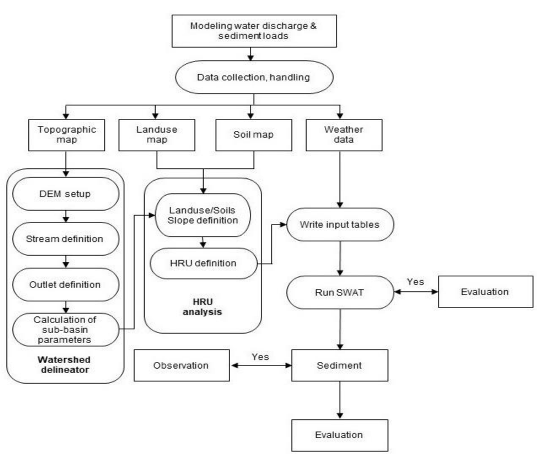


Figure 3: Flow chart of the methodology

The assessment of SWAT model was based on observed discharge data. The root mean squared error (RMSE), Nash - Sutcliffe Index (E), and coefficient of determination (R2) were used to evaluate the model performance. Specific values for the user to examine results are shown in Table 2.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i}-X_{model,i})^2}{n}},$$

$$R^2 = \frac{\sum_{i=1}^{n}(X_{obs,i}-\overline{X}_{obs}).(X_{model,i}-\overline{X}_{model})}{\sqrt{\sum_{i=1}^{n}(X_{obs,i}-\overline{X}_{obs})^2.(X_{model,i}-\overline{X}_{model})^2}},$$

$$E = 1 - \frac{\sum_{i=1}^{n}(X_{obs,i}-\overline{X}_{model,i})^2}{\sum_{i=1}^{n}(X_{obs,i}-\overline{X}_{obs})^2},$$

Where Xobs is an abbreviation of observed discharge at time (i) and Xmodel is the simulated discharge at time (i).

Table 2-Statistical indices [12]

R^2	>0.95	0.85-0.95	0.75-0.85	<0.75
E	>0.85	0.65-0.85	0.5-0.65	<0.5
Simulation level	Very good	Good	Medium	Poor

3 RESULTS AND DISCUSSION

3.1 Model Calibration and validation

Figure 4 shows the simulated and observed values for discharge at An Lao station and the comparison results were very good. The R coefficients in the calibration period are 0.82 and 0.71. On the other hand, the E coefficients in the validation period are 0.89 and 0.74, respectively. These values indicate good model performance. The RMSE coefficients in both the periods are relatively small 40.78m^3/s and 44.03m^3/s. The values distribution of observed and simulated discharge at the station are shown in Table 3.

The water discharge counted by month from 1995-2009 is shown in Figure 5a, the flow is mainly concentrated in the 4 months of the flood season (from months of September to December), and the largest in November. The flow parameters of the SWAT model for the river basin are shown in Table 4.

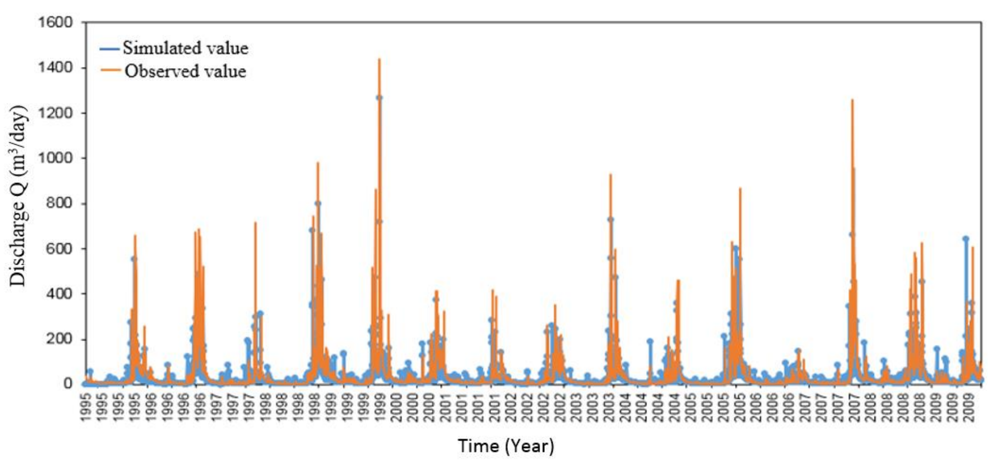


Figure 4: Calibrated (1995-2002), and validated (2003-2009) hydrographs of discharge at An Lao station

Table 3-The performance of the model for the simulation of flow-out at An Lao station

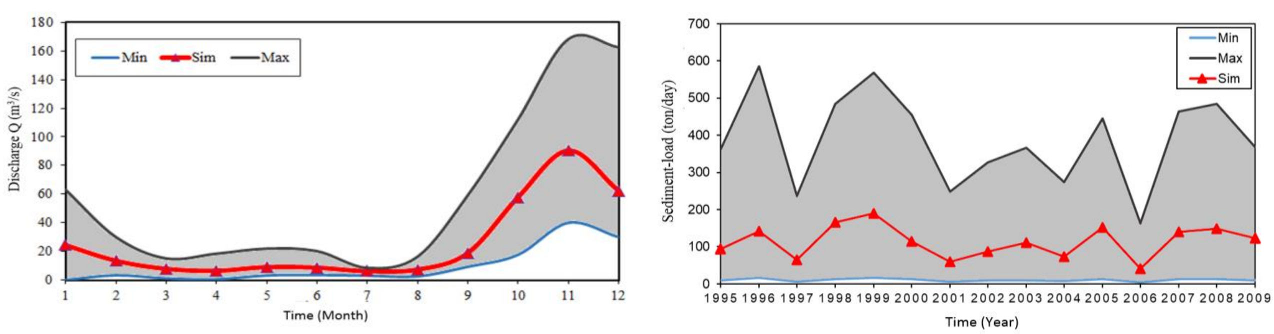
Station	Calibrated (1995 - 2002)			Validation (2003 - 2009)		
	RMSE (m^3/s)	R^2	E	RMSE (m^3/s)	R^2	E
An Lao	40.78	0.82	0.71	44.03	0.89	0.74

Table 4-Simulated values of using the parameters in SWAT model for streamflow

No.	Description of parameters	Parameter	Range of value	Fitted value
1	Initial SCS CN II value	CN2	35 - 98	40
2	Shallow aquifer's threshold water depth (flow)	GWQMN	0 - 5000	5000
3	Baseflow alpha factor	ALPHA_Bf	0 - 1	0.85
4	Channel effective hydraulic conductivity ($mm.h^{-1}$)	CH_K(2)	− 0.01 - 500	100
5	Groundwater "Revap" coefficient	GW_REVAP	0.02 - 0.2	0.1
6	Groundwater delay (days)	GW_DELAY	0 - 500	500
7	Surface runoff lag time (days)	SURLAG	1 - 24	10
8	Maximum canopy storage (mm)	CANMX	0 - 100	80
9	The shallow aquifer's threshold water depth (Revap (mm))	REVAPMN	0 - 500	0
10	Manning's "n" value for the main channel	CH_N2	− 0.01 - 0.3	0.01

From the calibration results and a good test of the flow, the details of the input data are detailed, fully describing the properties of each soil type through the parameters. The values of the parameters referenced by the data in the SWAT model library and the basins with similar soil types have been studied.

The average sediment load in many years at An Lao station is 113.79 ton/day (with the range of statistics from 11.52 ton/day - 388.37 ton/day) (Figure 5b). The sediment load parameters of the SWAT model for the river basin are shown in Table 5.



a. b.

Figure 5: a) The monthly average of flow, and b) The yearly average of sediment load at An Lao station

Table 5-The sediment related parameters of SWAT model

No.	Description of parameters	Parameter	Range of value	Fitted value
1	USLE equation soil erodibility, (ha.MJ.mm)	USLE_K	-0.34 - 0.2	0.1
2	The lowest value of USLE_C for water erosion (land cover/plant)	USLE_C	0.001 - 0.37	0.015
3	USLE equation support practice factor	USLE_P	-1.5 - 0.5	0.25
4	The exponential parameter for calculation of sediment restrained in channel routing	SPEXP	1 - 1.5	1.1
5	Maximum sum of sediment transported from a reach segment	SPCON	0.0001 - 0.01	0.01
6	Channel cover factor	CH_COV	0 - 1	0.5
7	The monthly erodibility factor of the main channel [cm/h/Pa]	CH_ERODMO	0 - 1	0.5

3.2 The sediment load calculation

In the Lai Giang river basin, statistics displays typically the sediment load in the entire examined area. Specifically, the results of the average sediment load counted in a year is shown in Figure 6.

Based-on the results of sediment load at Lai Giang river basin, the volume of sediment load was gathering into reservoir with 4 months in flood-season (from September to December in the same year). The highest volume of it is in the month of November. The average of sediment load during flood-season (from September to December) at Lai Giang river basin is 10706.66 ton and this volume is equal to 76.73% the total of the average sediment load per year (Table 6).

By the following statistics in the Table 6, the annual average volume of sediment load gathering to Lai Giang basin is 13954.17 ton.

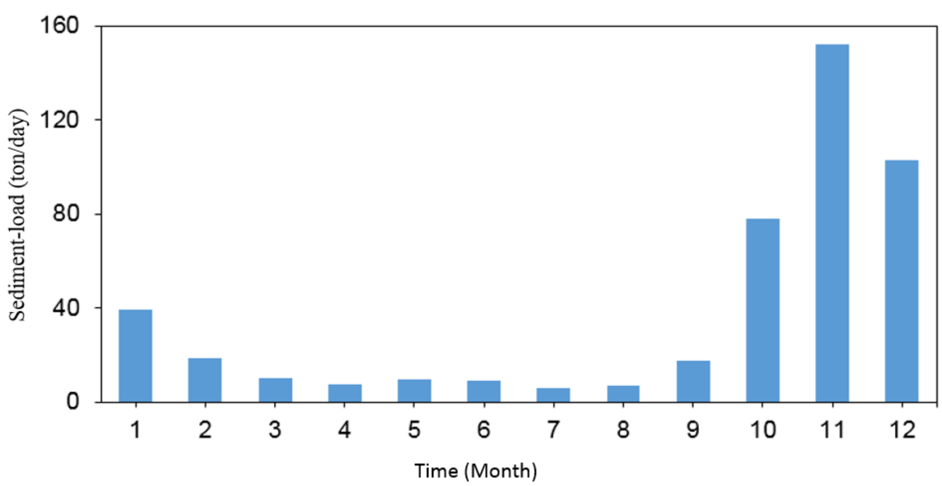


Figure 6: Monthly average sediment load

Table 6-The volume of sediment load at station

Station	The average volume of sediment load				
	Dry season (I-VIII)		Flood season (IX-XII)		The annual average volume of sediment (ton)
	The average volume of sediment (ton)	Percentage (%)	The average volume of sediment (ton)	Percentage (%)	
An Lao	3247.51	23.27	10706.66	76.73	13954.17

With regards to the practical implementation or application, the output of the paper could be considered as useful data for river and irrigation management in this study area.

4 CONCLUSION

Following conclusions can be drawn from the conducted study:

- The simulation of water discharge in Lai Giang river basin was carried out between the years 1995-2009 using SWAT model with comparatively good results because R^2 and E values were above 0.7. Therefore, it is appropriate to integrate GIS technology and SWAT model for water discharge simulation in Lai Giang river basin as well as for other river basins.
- The development of the volume of sediment load is suitable with the tendency of development of flow discharge. The average of sediment load during flood-season (from September to December) at Lai Giang river basin is 10706.66 ton and this volume equal to 76.73% the total of the average sediment load per year. The highest volume of it is in the month of November.

APPLICATION OF HYDRODYNAMIC MODELLING TO ASSESS THE EFFICIENCY OF HURRICANE PROTECTION MEASURE AT XOM RO DIKE, PHU YEN PROVINCE, VIETNAM

[a] Thanh Nhan Duc Tran, [b] Zeeshan Ahmed, [c] Ngoc Duong Vo
a, c: Water Resources Department, University of Science and Technology - The University of Danang, duc.dut.wr@gmail.com
b: Water Resources and Glaciology Department, Global Change Impact Studies Centre (GCISC),
zeeshanahmed44@outlook.com

Abstract- Coastal erosion is a phenomenon caused by anthropogenic impact and climate change in recent years. With a rise in highly unpredicted frequency of hurricanes, wave impact on the coasts lead to debris removal and coastline erosion. Sudden sea level rise and unstable surge made by unpredicted trajectory of severe wave impacts could be considered as the main cause of erosion and destruction of coastal constructions such as sea dike, especially in the Xom Ro sea dike in the central Vietnam, which has important mission to protect citizens life and properties of Phu Yen province. The present study is based on the coastal region modeling using hydrodynamic model Mike 21 from Binh Dinh to Binh Thuan province and particularly for the Xom Ro sea dike, Phu Yen province. By assessing different scenarios of hurricane protection of the Xom Ro sea dike under simulated hurricane (level 6, 9 and 12), this study will help to have comprehensive views of the affection of coastal protection measures along with detailed assessment of coastal shoreline status before and after extreme weather conditions.

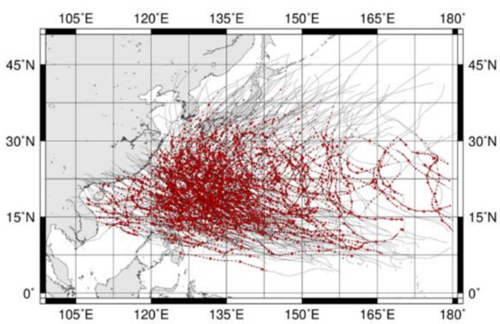
Keywords- Climate change, flood, hurricane, Hydrodynamic modeling, coastal erosion.

1 INTRODUCTION

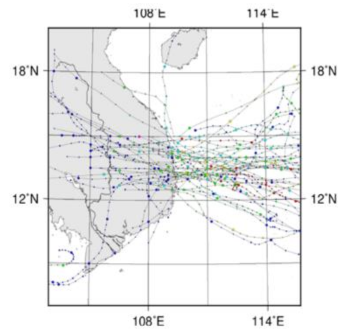
One of the factors that plays a key role on socio-economic development of Vietnam is the "sea". The issues related to coastal erosion can be separated into two main distinguished categories: (a) long-term processes that leads to gradually collapse of coastal shoreline, and (b) episodic processes such as hurricanes, tidal surges and tsunami, which suddenly changes the morphological shape of coastal shoreline and bring significant loss to coastal landforms [1].

The Eastern Sea of Vietnam is in the North-West Pacific (NWP) territory, where there is a high ratio of getting hurricanes. Indeed, extreme weather conditions and severe wave impacts due to anthropogenic actions, disasters such as unexpected hurricane, storm and high sea level rise creates a huge loss of economy and human properties [2]. Vietnam coastline, 3,260 km long (excluding islands), is one of most vulnerable parts effected by Eastern Sea yearly (Figure 1). The central Vietnam consists of a long coastline with many resources, having great potential and advantages for economic development. There are basically 88 erosional sites in the area of above 120 km, alongside the central coast of Vietnam. The coast of the Central Vietnam is experiencing coastline changes at significant rates year by year, mainly at three regions: Thuan An beach - Hue city, Cua Dai beach - Quang Nam province, and Xom Ro commune - Phu Yen province. The significant cause of this is the impact of floods during wet season along with climate change response by anthropogenic influence [3]. In this study, the coastline changes are observed along the coastal areas of central Vietnam. Nowadays, there are many techniques used to solve these problems, but the mathematical modelling is one of the most productive and appropriate explanations. Due to lack of observed data, previous studies are based on the results extracted from earlier finding. Thus, the probability of an error always exists in such condition. However, the present study focuses on a complicated area having high amount of hurricanes every year and other unpredictable factors (tidal processes and sea-water surge). To solve the aforementioned problems, this paper used a double model (East sea model & case study model), with an important observed data of East sea boundary to alleviate the error in results. This study would hope to use hydrodynamic modeling to provide useful data for coastal enhancement and disaster management for coasts in Vietnam central region, notably for Phu Yen province.

Besides, this research also assesses the hurricane protection of Xom Ro sea dike with three different scenarios based on simulated hurricane. Consequently, this study aims to evaluate the effects of threatened physical factors that changes the coastal morphology in central Vietnam and in the specific area for case study at Xom Ro commune - Phu Yen province.



a.



b.

Figure 1: Yearly hurricanes trajectory with level 12, a) NWP, and b) central Vietnam [4]

2 MATERIAL AND METHODS

2.1 *Numerical modelling*

Mike 21 SW belongs to Mike software family of DHI was used in this study [5]. The discretization of the governing equation in geographical and spectral space was performed using cell center finite volume method. In the geographical area, an unstructured work strategy was utilized. The time joining was performed utilizing a fragmentary advance methodology where a multi-grouping express strategy was applied for the spread of wave activity. MIKE 21 SW incorporates the physical phenomena as follows:

$$\frac{\partial N}{\partial t} + \nabla.(\vec{v}.\mathrm{N}) = \frac{\mathrm{S}}{\sigma} \qquad (1)$$

Equation (1) says:

N (σ, θ): wave's frequency.

t: time.

$\vec{v}$: (C_x, C_y, C_σ, C_ϕ): : wave's velocity in 4D environment.

∇: the difference equation in $\vec{v}$, σ and θ.

2.2 *Model set up*

MODEL 1 (EAST SEA MODEL)

The East Sea model was used to simulate the tidal processes, waves, and sea-water surge from the offshore areas to coastline areas. Figure 2 reveals the model structure and the boundaries of the model from Mindoro, Taiwan, Luzon, Babalac, and Malacca. In hydro-dynamic (HD) module, these boundaries contain the water level boundary data and tidal data which are built from harmonic constants. With the SW (wave spectrum) module, these boundaries are considered as the supposition of "lateral boundary". According to quality demand, the grid in the study area was divided into smoothest levels. The grid was also divided at a smaller level for better results in the shallow coastal areas.

MODEL 2 (XOM RO SEA DIKE)

To evaluate the hurricane protection efficiency of the Xom Ro sea dike in the simulation with the hurricane LINGLING, it was decided to separate this 2D model into three scenarios as:

- Scenario 1: Evaluation of Xom Ro areas without sea dike system.
- Scenario 2: Xom Ro sea dike (modified) by cutting off 3 sea dikes in the original design with 12 sea dikes, keeping the original length (970.65m).
- Scenario 3: Original design of sea dike system with 12 sea dikes.

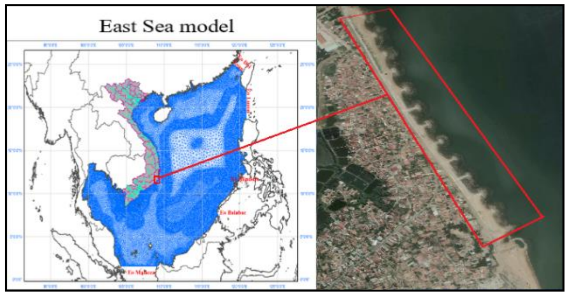


Figure 2: The model structure & boundaries - East sea model

The range and grid of the different scenarios in the study is shown in Figure 3. The spatial range of the calculated model was chosen large enough to ensure that it could minimize the influence of uncertain factors which were in the boundaries of the simulated models.

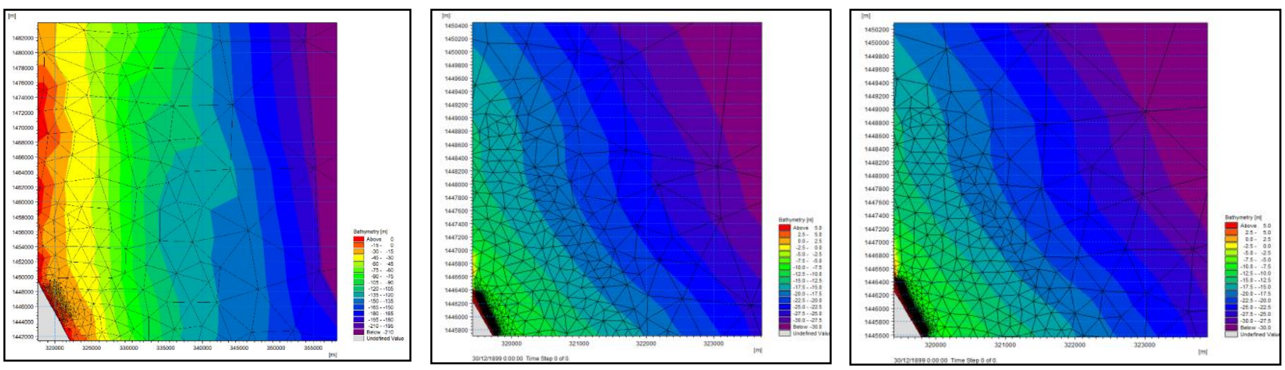
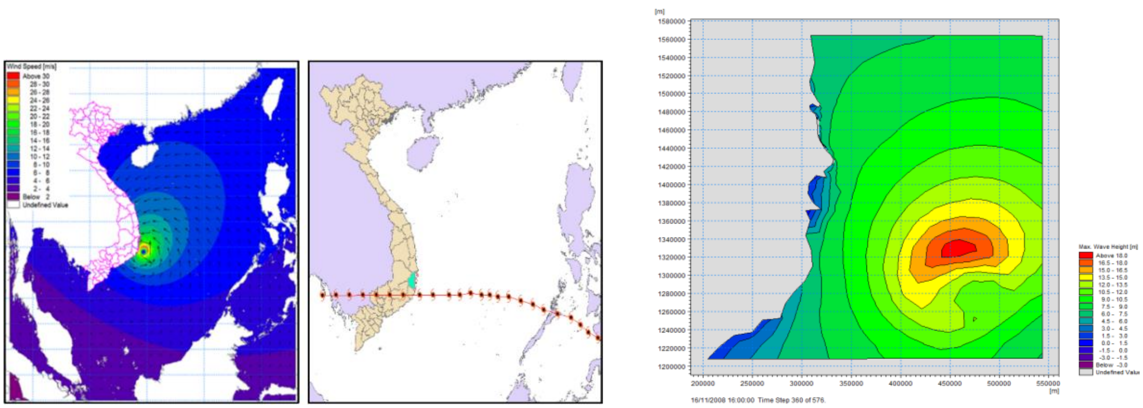


Figure 3: The model 2 structure of Scenario 1/ Scenario 2/ Scenario 3

The model grid was an unstructured mesh with the triangle components. In areas with complex topography, the grid was divided more smoothly to evaluate comprehensively the impact of the Xom Ro sea dike to decrease wave max height in SW module. The study area was set up on the basis of 10m ÷ 15m together with a total of 7367 elements.

2.3 Data and material

The topographic details of supplementary study areas of the eastern sea of Vietnam were acquired from SRTM15_PLUS V1.0 of Scripps Institute of Oceanography, University of California, USA. This was a dataset of 15″×15″ resolution (about 450m) [6]. The tidal water level data was gathered and tuned, referring to the national elevation system. Real wave data was extracted from Phu Quy & Con Dao meteorology stations (1995 - 2015). With regards to other meteorological data used in this study i.e. atmospheric pressure and wind forcing data, were obtained from the CFSR (Climate Forecast System analysis) of the National Center for Environmental Prediction - National Oceanic and Atmospheric Administration Commissioned Corps (NCEP / NOAA) [7]. The LINGLING hurricane was formed on November 6, 2001 and ended on November 12, 2001 and its data was collected from Japanese meteorological agency [8]. The average speed of the whole hurricane is 15.2 (km/h). The forecasted trajectory of this simulated hurricane in this study was based on the trajectory of LINGLING hurricane (2001), with the movement around 205 km to the South. This hurricane LINGLING (level 12) is one the most typical hurricane in Vietnam in recent years and it could be considered as a good data for simulation of different scenarios. The selection of predicted hurricane trajectories is important to simulate sea-water surge, the values of wave extreme is the principle which are based on statistics of the trajectories of hurricanes affecting this study area in the past. The selection of the type of its orbit is likely to cause the largest seawater surges and waves. The Vietnam coast is in the northern hemisphere, the wind rule of the hurricane always has a counterclockwise spiral, so in theory, the hurricane will cause the seawater surges to the North. The area with the highest wind speed during a hurricane is usually distributed within 30 - 70 km in the radius of the center of the hurricane, with the max wave height above 18m.



a. b.

Figure 4: a) Wind & trajectory of hurricane LINGLING, and b) Simulated hurricane LINGLING

The summary of the hurricanes and tropical depressions that were affecting Phu Yen province in the period of 1951 - 2015 could be seen that it is having a similar orbit in the East-West direction. This is also the type of orbit that can create the most dangerous waves surge to the coastal areas when the hurricane reaches to the mainland. Among the hurricanes mentioned above, LINGLING (2001) was one of the strongest hurricanes and it had a complicated orbit in East-West direction, so finally, it was selected for the simulation in this research (Figure 4a, b).

2.4 *Calibration and validation at Model 1*

The calibration and validation of model 1 was based on the observed and collected data extracted from reliable sources i.e. real wave data at Phu Quy & Con Dao stations and sea tide data from Global tide FES2014 model (Satellites monitoring data of AVISO organization) [9]. Figure 5 shows the locations of 55 testing points (P1 ÷ P55), in which the tidal water surge levels were predicted and the locations of coastal navigation stations in the islands. The primary thing for adjustment of the SW model is the bed resistance with the Manning's coefficient.

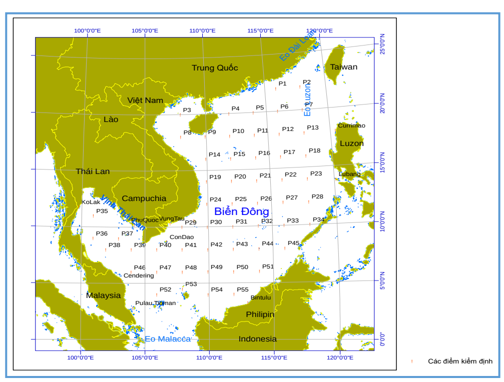
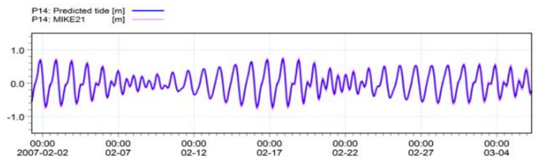
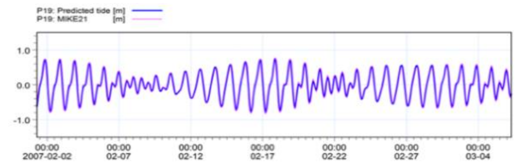


Figure 5: The comparison of points between Model 1 & FES2014

The results were compared in Figures 6 and 7, in which, these comparations illustrate the correlation between results in Model 1 and forecasted tide (global tide FES2014 model) at important & typical point: P14, P19, P24 and P30. These results were compared with high correlation coefficient as 0.98 and 0.99 (Figure 8) with pre-defined periods 1/1/2001 - 12/31/2001.

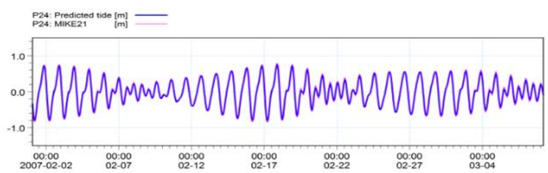


a.

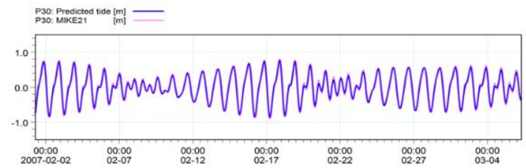


b.

Figure 6: The water level contrast between Model 1 and the Global tide FES2014 model, a) point P14, and b) point P19



a.



b.

Figure 7: The water level contrast between Model 1 and the Global tide FES2014 model, a) point P24, and b) point P30

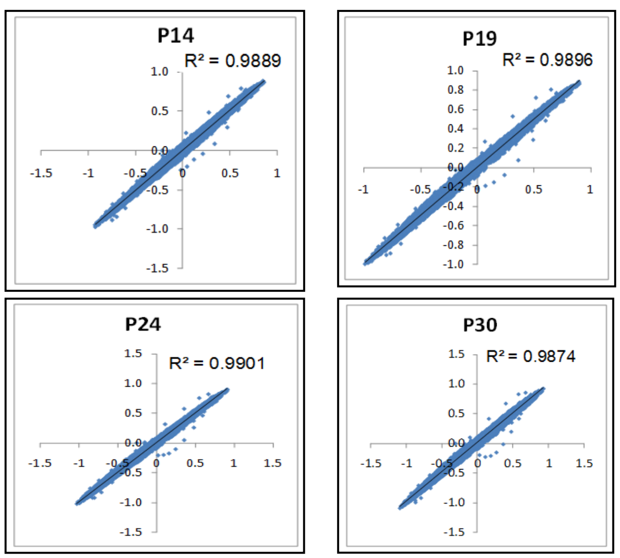
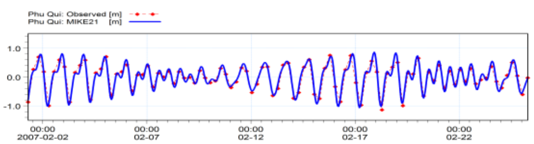
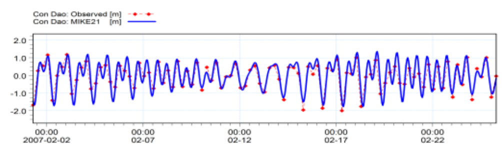


Figure 8: Sea level correlation among Model 1 and Global tide FES2014 model at points P14, P19, P24 and P30

The observed data was extracted from meteorology stations in Phu Qui and Con Dao for the enhancement of Model 1, shown in Figure 9.



a.



b.

Figure 9: The comparison of water level between Model 1 and observed data collected, a) at Phu Qui station, and b) at Con Dao station

2.5 Calibration and validation at Model 2

In this study, it was decided to use the nearest station - Quy Nhon station due to lack of stations for calibration and validation of Model 2 at Phu Yen province. The calibrated and validated results consisting of real values of water level data of Quy Nhon station (November 2007 and December 2009) are presented in Figure 10.

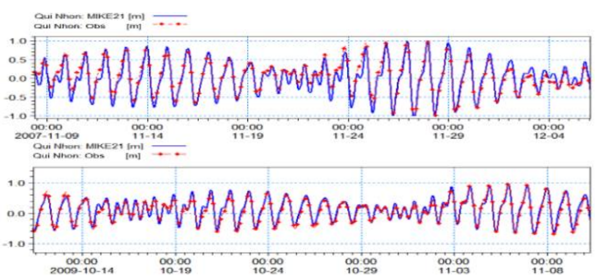
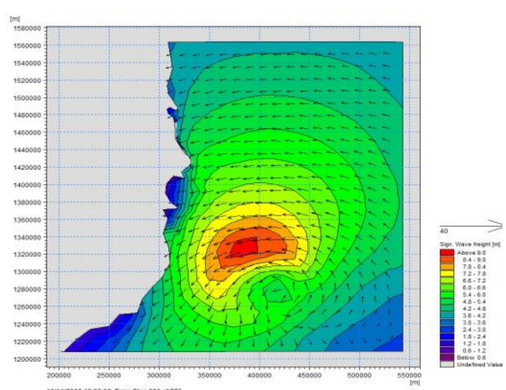


Figure 10: The comparison of water level between Model 1 and observed data collected at Quy Nhon station

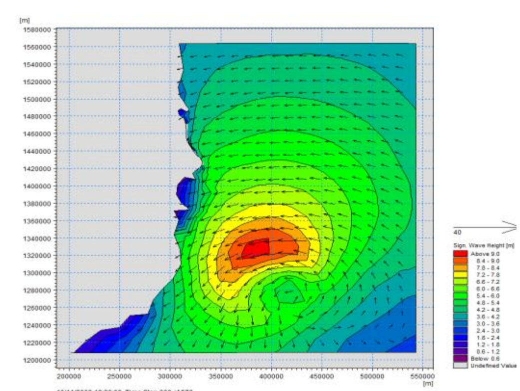
The second model was calibrated using Quy Nhon observed data. The calibration and validation results of the model 2 in November 2007 and December 2009 presents high similarity and it could be considered as good quality for application.

3 APPLICATION

The influence of hurricane LINGLING (level 12) is compared with Xom Ro area based on two criteria's as sea wave direction and highest height wave level.

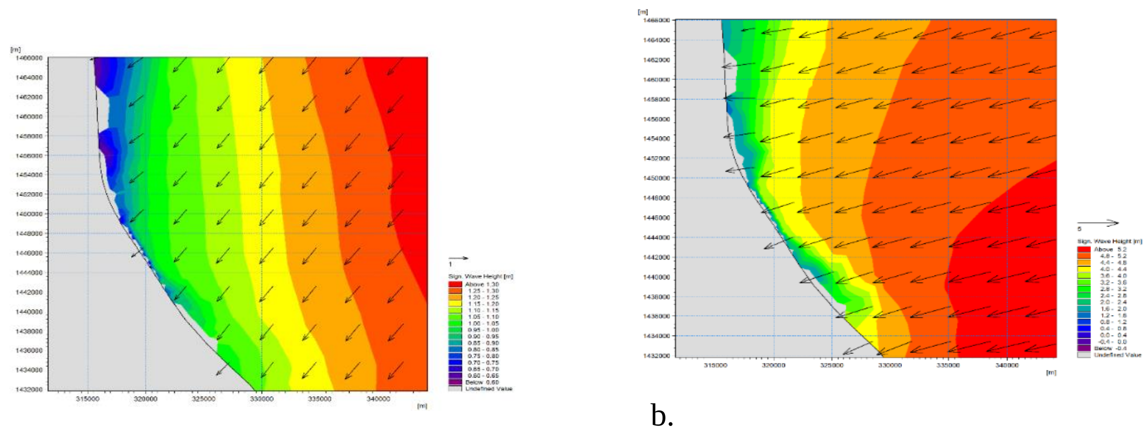


a.



b.

Figure 11: Wave height distribution, a) with hurricane event level 12 in East sea, and b) with impact of hurricane event when reaching Phu Yen province



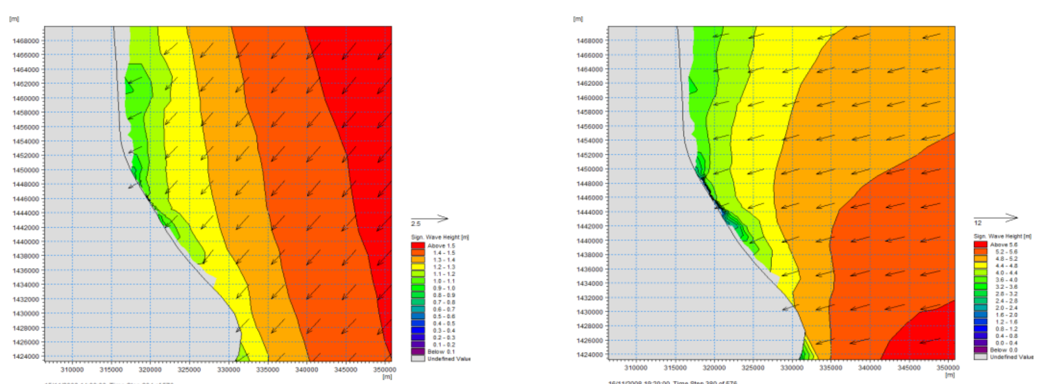
a. b.

Figure 12: Wave height distribution, a) with hurricane event level 12 in East sea in Scenario 1, and b) with impact of hurricane event when reaching Phu Yen province in Scenario 1

Wave height distribution with hurricane event in East sea were more in South-West direction while that feature turn to straight West when reaching mainland at Xom Ro sea dike. Also, there is a preliminary assessment with similar wave height distribution in three simulated scenarios in the same periods for two cases before (Figure 12a, 13a, 14a) and after (Figure 12b, 13b, 14b) the hurricane reaches mainland.

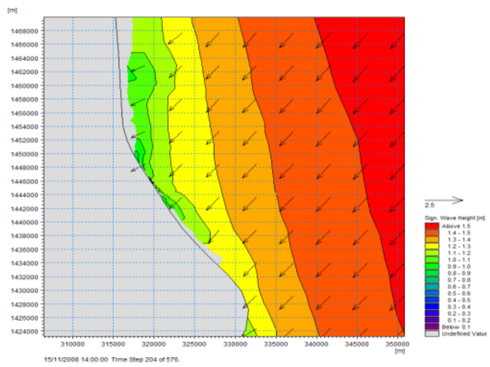
Along with model 1 & 2 simulations, this study assesses the hurricane protection efficiency of Xom Ro sea dike, which undertake main responsibility of the safety of Xom Ro commune as well as Phu Yen province. The selected 3 assessed points are t_1, t_2 and t_3 which affected significantly by hurricane impacts (Figure 15).

The results illustrate that the wave reduction effect of scenario 3 is the best when compared with the rest results (Table 1). The practical application of simulated results can be utilized by the industry to predict future hurricanes with the same intensity and its effect to the coastline protection construction.

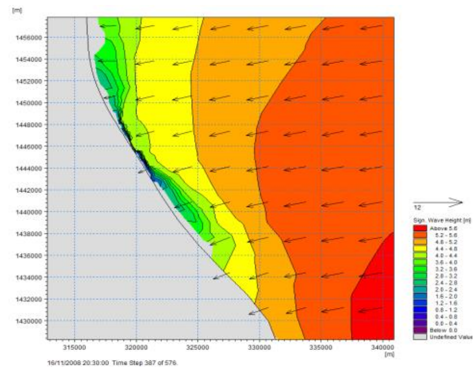


a. b.

Figure 13: Wave height distribution, a) with hurricane event level 12 in East sea in Scenario 2, and b) with impact of hurricane event when reaching Phu Yen province in Scenario 2



a.



b.

Figure 14: Wave height distribution, a) with hurricane event level 12 in East sea in Scenario 3, and b) with impact of hurricane event when reaching Phu Yen province in Scenario 3

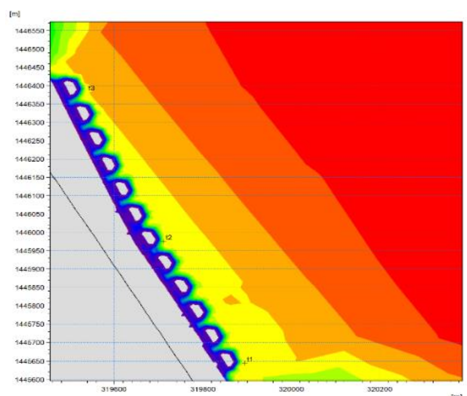


Figure 15: Location of 3 assessed points at Xom Ro sea dike (t_1, t_2 and t_3)

Table 1-Wave height distribution in 3 scenarios

Point	Scenario 1	Scenario 2	Scenario 3
t_1	4.35m	4.33m	4.34m
t_2	4.34m	3.05m	2.81m
t_3	4.27m	2.41m	1.67m

4 CONCLUSION

Following conclusions can be drawn from conducted study:

- The study has simulated and assessed the impact of simulated hurricane LINGLING (2001) level 12 for case study at Xom Ro sea dike in 3 different scenarios. The structural efficiency of hurricane protection measure is reached to its peak with the scenario 3 (original design) when compared with the rest results. Indeed, the maximum wave height in scenario 3 is 4.34m (t_1) and it decreases to 1.67m in the position t_3, but it decreases only 1.92m in the scenario 2 and approximately remains unchanged in the scenario 1 (half of sea dikes decreased).
- The simulation of models is performed, calibrated, validated, measured, and observed via using strong sources from meteorological stations, forecasted results from the Global tide FES2014 model along with satellite observation. The quite accurate results in 2 models conclude the confidence of applications for other purposes.

- Scenarios illustrate the best efficiency of original design of Xom Ro sea dike as well as provide details of peak wave height as aforementioned demonstration. As the result, these results extracted from case study could be considered as valuable consultation for coastal planning & coastal disaster management.

A future direction for this study is to re-set up models with the actual shape, specific materials, enhance the preciseness of dimension as well as other properties of the construction would play vital role for having better results.

ACKNOWLEDGEMENTS

The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] A. Rajawat, H. Chauhan, R. Ratheesh, S. Rode, R. Bhanderi, M. Mahapatra, K. Mohit, R. Yadav, S. Abraham, S. Singh, K. Keshri and Ajai, "Assessment of coastal erosion along the Indian coast on 1:25000 scale using satellite data of 1989-91 & 2004-06 time frames," 2015.

[2] R. Ratheesh, A. Ritesh, P. Remya, K. NagaKumar, G. Demudu, A. Rajawat, Balakrishnan and N. Kakani, "Modelling coastal erosion: A case study of Yarada beach near Visakhapatnam, east coast of India," in *Ocean & Coastal Management*, 2018.

[3] E. Gilman, J. Ellison, N. Duke and C. Field, "Threats to mangroves from climate change and adaption options: A review," in *Aquat Bot*, 2008.

[4] "Digital Typhoon: Typhoons, Hurricanes and Cyclones," National Institute of Informatics (NII), [Online]. Available: http://agora.ex.nii.ac.jp/digital-typhoon/help/world.html.en.

[5] "DHI," 2020. [Online]. Available: http://www.mikepoweredbydhi.com/.

[6] C. Olson, J. Becker and D. Sandwell, "A new global bathymetry map at 15 arcsecond resolution for resolving seafloor fabric: SRTM15_PLUS," in *AGU Fall Meeting Abstracts*, 2014.

[7] S. Saha, S. Moorthi, X. Wu, J. Wang, S. Nadiga, P. Tripp and M. Iredell, "The NCEP climate forecast system version 2," *Journal of Climate 27(6)*, vol. 27, no. 6, pp. 2185-2208, 2014.

[8] "Japanese Meteorological Agency," Natioal Institute of Informatics (NII), [Online]. Available: http://agora.ex.nii.ac.jp/digital-typhoon/.

[9] "Aviso+: altimetry satellite data and products for ocean," [Online]. Available: https://www.aviso.altimetry.fr/.

SECOND STAGE STILLING BASIN AS A SOLUTION FOR CHASHMA BARRAGE DUE TO DAMAGE CAUSED BY RETROGRESSION PHENOMENON

[a] Ijaz Ahmad, [b] Noor Muhammad Khan
a: Centre of Excellence in Water Resources Engineering, University of Engineering and Technology, Lahore 54890, dr.ijaz@uet.edu.pk
b: Centre of Excellence in Water Resources Engineering, University of Engineering and Technology, Lahore 54890, noorkhan@uet.edu.pk

Abstract- Chashma Barrage located on the Indus River in district Mianwali was constructed in 1971 as a part of Indus Basin Project. The Barrage is different in the sense that it has some storage capacity for regulation of water for irrigation releases, power generation and supply of cooling water for Chashma Nuclear Power Project. The riverbed below Chashma barrage has been degrading since its commissioning in 1971. This has resulted in low tail water levels for the whole range of discharges, and consequent deterioration in the performance of stilling basin of the barrage. For the maximum flood record of 1,038,873 cusecs observed in 2010, the tail water level was 5.3 ft. lower than design value. Similarly, for flood discharge of 636,000 cusecs in 2015, the tail water level was lower to the extent of 6 ft. from the designed figure. For discharges of 500,000 cusecs and below the tail water level is lower by 5 ft. on the average. Observations show that in general, tail water lowering has continued even after the record flood of2010. As a result of lowering tail water levels, the required conjugate depth for formation of hydraulic jump is not attained with the consequence of inadequate jump formation and the passage of undissipated energy downstream, causing scour and damages to stone apron, as a recurring feature. Solution for the formation of a stable jump on the protected area could be achieved from either of following options: Construction of a secondary weir and addition of an auxiliary stilling basin of appropriate length with a lower floor level, immediately below the existing stilling basin floor.

Keywords- Chashma Barrage; Stilling Basin; Retrogression.

1 INTRODUCTION

Chashma Barrage is located on the Indus River about 56 km downstream of Jinnah Barrage. The barrage supplies water to the Chashma Jhelum Link (CJ Link) Canal on the left bank and Chashma Right Bank Canal (CRBC) on the right bank. The cooling water supplies for the Chashma Nuclear Power Plant are also taken from the barrage through the CJ Link. A 184 MW hydropower plant was constructed subsequently on the right bank and was commissioned in the year 2001. Chashma Barrage, unlike other barrages in Pakistan has water storage capacity to regulate releases for irrigation and now for power generation also. The maximum and minimum designed reservoir levels are RL 649 ft. and 637 ft. respectively. The storage at the Barrage was designed to re-regulate the releases from Tarbela and floods of tributaries below Tarbela. The re-regulation and flood absorption capacity of the Barrage has, however, reduced significantly due to reduction in storage capacity as well as need for maintenance of pond for power generation. According to the survey of 2012, gross, live, and dead storage capacities have reduced from 0.87 to 0.348, 0.72 to 0.289 and 0.15 to 0.059 MAF. Chashma barrage received 82.0 MAF per annum on average basis, for period from 1998 to 2015, with minimum inflow of 62.9 MAF in year 2001, and a maximum inflow of 100.1 MAF in 2010. In last five-years period of 2011 to 2015, average inflow volume at Chashma barrage is computed as 82.7 MAF. As such during last five years barrage has received nearly average flows (82.7 vs. 82.0 MAF).

The maximum design discharge for the barrage is 950,000 cusecs through the gates whereas the downstream energy dissipation works are designed for 1,100,000 cusecs to account for 20% discharge concentration. Some 84,000 cusecs can be released through powerhouse since 2001. Theoretically this flow should not be considered in flood passing capacity of the project, as powerhouse is supposed to be closed if sedimentation concentration is high. Maximum historic peaks of flood passed through Chashma Barrage show that peak discharge of 1,038,873 cusecs that passed through barrage on 1st August 2010 was of 'Exceptionally High' category. Prior to 2010 the highest discharge of 786,600 cusecs passed on 3rd August 1976. 'Very High Flood' has also been observed in year 1992, and in year 2013. All other flood peaks, in the history of the barrage, remained as 'Low' or 'Medium' or 'High' flood stage/category.

The Chashma Barrage is 47 years old now and the riverbed below the barrage has been degrading since its commissioning, which resulted in low tail water levels for the whole range of discharges, and consequent deterioration in the performance of stilling basin of the barrage. Due to higher flow velocities now exiting at stilling basin has caused retrogression phenomenon which has shown a threat to the whole structure. It is necessary to point out that due to tail-water degradation, flow velocities exiting the stilling basin are now 17 to 22 % higher than those of the design and may reach 16 ft. per second in some standard bays and 18 ft. per second in certain under sluice bays. In addition to causing degradation of bed, such high velocities are instrumental in pushing the stone apron downstream which after displacement is heaped up as velocities fall in the wider river section below. In view of greater velocities now exiting at stilling basin, it may be necessary to review the existing conditions and propose new design specifications for the barrage which maybe second stage (or auxiliary) stilling basin as a solution for Chasma Barrage due to damage caused by retrogression phenomenon.

2 LITERATURE REVIEW

Valero et al. [1] investigated the performance of USBR Type-III stilling basin by using numerical simulations for eight different Froude numbers (F) ranging from 3.1 to 9.5. The steps cause an even higher decay of the maximum velocity within the basin. This decrease is more pronounced for smaller Froude numbers. Also, baffle blocks promote maximum velocity decay. Babaali et al. [2] performed computational modeling of the hydraulic jump in the stilling basin with convergence walls using CFD codes and concluded that the stilling basin has been accepted to be the most powerful hydraulic structure for the dissipation of the flow energy. The size and geometry of the stilling basin affect the formation of flow patterns, which can be influential for hydraulic performance of the whole system.

Jalut and El-Baaja [3] performed experimental studies for energy dissipation using stilling basins with one and two consecutive drops. This study presents the results of an experimental approach consisting of 1080 runs to achieve minimum length of hydraulic jump and maximum energy dissipation downstream of hydraulic structures using stilling basins with one drop and two consecutive drops. Rajaratnam and Hurtig [4] in the laboratory experiments have shown that screens or porous baffles with a porosity of about 40% could be used as effective energy dissipaters below hydraulic structures, either as a single wall or as a double wall. The experiments were carried out for a supercritical Froude Numbers from 4-13 and the relative energy dissipater was appreciably larger than produced by the corresponding classical hydraulic jump. In another study, a physical model was constructed to determine the size and placement of riprap downstream of Saint Anthony's Fall (SAF) stilling basins to ensure basin integrity [5]. The results show that the riprap size required for stability increases exponentially with the Froude Number and that larger riprap is required for stability if riprap is placed at the end sill level, compared to the placement at the basin floor level. Relationships are presented to determine the minimum size and length of riprap required to ensure basin integrity.

Moreover, Barjastehmaleki et al. [6] sought to reduce the severe pressure fluctuations in order to minimize damage to the stilling basin and the impact of Froude number, spillway length and width on the hydraulic characteristics and the water surface profile in different conditions. Higher value of The Froude number results in increased length of jump. (i.e. Fr = 2; L = 10m, Fr = 4; L = 35m, Fr = 6; L = 50m). With lower values of Froude number hydraulic jump will happen near the overflow toe which will cause higher energy dissipation and lower extent of erosion for the basin body. But if the hydraulic jump occurs in greater distance, lower amounts of energy will be dissipated, and basin body will be under greater risk of damage, which won't be economical and efficient. Type I stilling basin is more compatible with Froude numbers of $1 < Fr < 2.5$. Therefore, for optimal and economical design of type I stilling basins, we should avoid large Froude numbers because this type of basin is effective up to the Froude number of 3, and barely covers the larger values. Kim et al. [7] reported on the deterioration in the performance of the stilling basin of the Chasma barrage, as a result of lowering of tail water levels, the required depth conjugate depth for formation of hydraulic jump is not attained with the consequence of inadequate jump formation and the passage of un-dissipated energy downstream, causing scour and damages to baffle block, concrete block and stone apron. Solution for the formation of a stable jump on the protected area could be achieved from addition of an auxiliary stilling basin of appropriate length with lower floor level, immediately below the existing stilling basin floor. This will release the flood flows from barrage to riverbed at appropriate tail water depth. Construction of auxiliary basin could be easily managed during the present regime of barrage operation. Jüstrich et al. [8] the residual flow energy will produce scour in an alluvial riverbed if no mitigation structure (such as a dissipation basin) is installed downstream of a grade control structure. In the absence of a technical dissipation structure or a downstream apron, scour can occur in a loose riverbed downstream. Meftah et al. [9] investigated the effect of a W-weir (without upstream or downstream apron) on the downstream sediment transport processes, focusing on the scour-hole formation. The maximum scour depth was observed a short distance downstream of the weir, independent of the boundary conditions. Carvalho et al. [10] confirmed that the case of fully filled floor gave the smaller values of scour parameters. The experimental works were carried out by Abdelhaleem [11] indicated that the floor blocks should occupy between 40% and 55% of the floor width and the most favorable conditions result when the baffles are placed perpendicular to the incoming flow.

3 METHODOLOGY

3.1 Data collection

To collect and review all the available data concerning the weir such as discharge design, cross section and long section of the weir is provided by WAPDA, Lahore. The barrage has 52 bays of 60 ft. width each including seven (7) under-sluice bays on the left and four (4) under-sluice bays on the right. In addition, a fish ladder and navigation lock form part of the barrage. It is a glacis type weir, fitted with radial gates, with crest level in standard bays at El. 622ft. and in under-sluices at El.617 ft. The normal pond level is El.642 ft. and storage pond level at El. 649ft. The barrage was designed for a 100-year flood equivalent to 950,000 cusecs but it successfully passed the exceptional high flood of 10,38,873 cusecs in year2010.

The stilling basin of the main weir is 140.6 ft. long with its floor level at El.604 ft. It has two rows of impact blocks downstream of glacis and two rows of baffle blocks at the end of concrete floor, followed by concrete blocks apron and flexible stone apron. The stilling basin of the under-sluices is comparatively longer (by about 20 ft.) and set at 5 ft. below the floor level of the main weir. The stilling basin design has been developed based on model studies and does not conform to any standard USBR type basin. It also allows for flow concentration of 20 %. The off-taking CJ Link canal has a regulator with 8 bays of 40 ft. width each, while the Chashma Right Bank Canal has its regulator with 2 bays of 40 ft. width each.

3.2 Damages to Concrete Block Apron and Flexible Stone Apron

Below the concrete stilling basin, the barrage is provided with 40 ft. long concrete blocks apron, consisting of concrete blocks of size 5 ft. x 5 ft. x4 ft. laid over 2 ft. thick inverted filter. It is followed by a flexible stone apron which is 5 ft. thick and 104 ft. long. In the recent event, nearly 40 to 60 blocks were settled or dislodged, and a few were reported to have been carried downstream by the river current for a distance of 100 ft. The extent of settlement of blocks between bays 50/51 and in front of bay 49 ranged between 0.4 to 4.5 ft over a length of 60 to 75 ft. The filter material filled in the gaps between the blocks has been totally washed out. Considering the severity of the event, the filter material beneath the blocks might have been also washed out. The relief wells in the affected part were also damaged. In addition, a scour pit of considerable size developed below dislodged concrete blocks. Stone apron downstream of concrete blocks has also been disturbed and pushed downstream by the river current as shown in Figures 1 and 2.

It is necessary to point out that due to tail-water degradation, flow velocities exiting the stilling basin are now 17 to 22 % higher than those of the design, and may reach 16 ft. per second in some standard bays and 18 ft. per second in certain under sluice bays. In addition to causing degradation of bed, such high velocities are instrumental in pushing the stone apron downstream which after displacement is heaped up as velocities fall in the wider river section below. The flexible stone apron is the first line of defense against riverbed degradation below the barrage. The 104 ft. long and 5 ft. thick stone apron provided at Chashma Barrage is expected to launch at 30^{o}angle and provide protection from scour. The stone specified by designers is of weight 40-250 lbs., 80 percent of which is to be heavier than 80 lbs. and not more than 5 % to be less than 40 lbs. In view of greater velocities now exiting at stilling basin, it may be necessary to revise the specifications for stone apron to minimize quantity of stone used to carry out annual O & M of flexible stone apron.

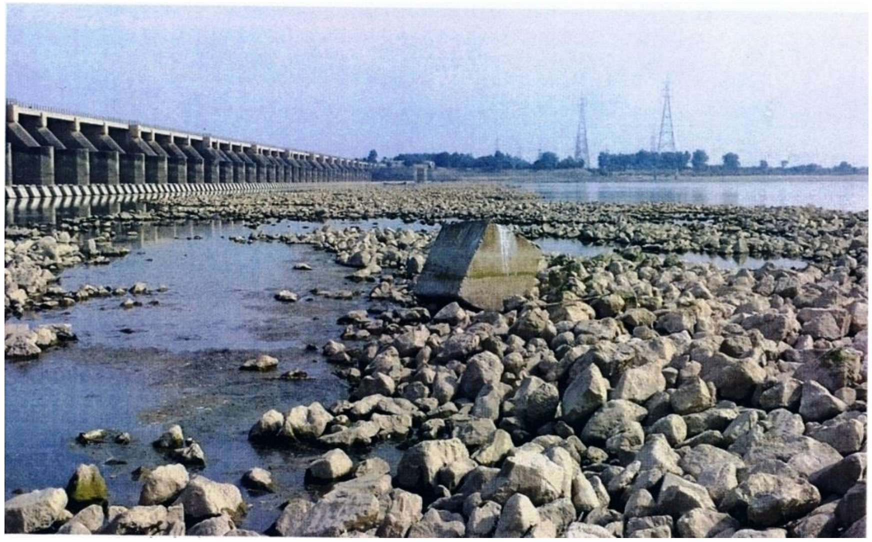


Figure 6: Dislodged concrete block carried away by river current in Front of Bay 51

Figure 7: View of settled concrete blocks right under-sluice

4 RESULTS AND ANALYSIS

4.1 *Degradation of Tail Water Levels*

The tail water rating curves provides estimated tail water levels for normal river state, accreted state, and retrogressed state for the range of river discharges at site. It may be observed that a retrogression of 5 ft. was allowed at higher discharges and 10 ft. at low discharges. The retrogressed levels are however used to check the design for proper submergence of hydraulic jump and adequate energy dissipation.

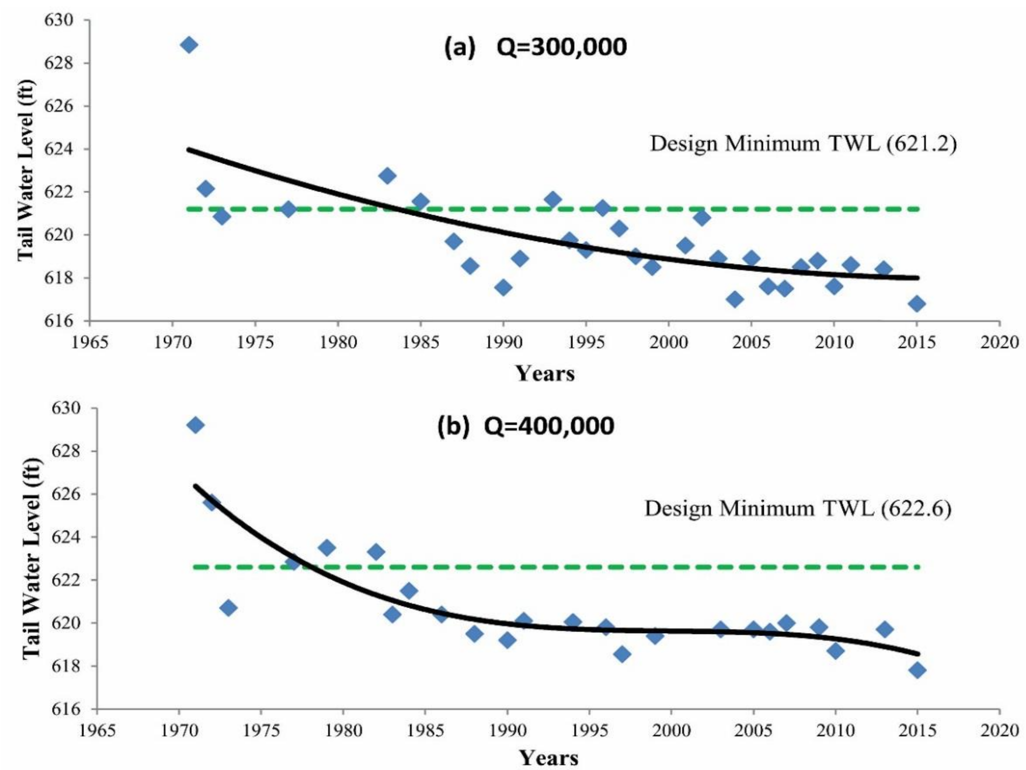
The data of minimum tail water levels observed against various discharges for the period from 2002-2016. This information has been used along with tail water levels reported for flood peaks of various years to estimate the present tail water rating curve in retrogressed state. It may be observed that existing retrogressed levels are 5 to 8 ft. lower than the design retrogressed levels over the whole range of discharges. For the flood of discharge 1038873 cusecs observed in 2010, the reported tail water was 5.3 ft. lower than the design retrogressed level. Similarly, for discharge of 636,000 cusecs observed in 2015, the tail water was 6 feet lower than design retrogressed level. The recent tail water (minimum) data for various discharges in 2013 and 2015 is given in Table 1. It may be observed that for lower discharges up to 200,000 cusecs, tail water level may be improving or rebounding, but this is not the case for higher discharges, for which tail water degradation is continuing.

Table 1: Tail Water Levels for 2013 & 2015

Years	**Minimum Tail Water Levels for Various Discharges**							
	20,000	50,000	100,000	200,000	300,000	400,000	500,000	600,000
2013	607 ft.	610.9 ft.	613.2 ft.	615.7 ft.	618.4 ft.	619.7 ft.	620.8 ft.	621.8 ft.
2015	609 ft.	612.1 ft.	613.7 ft.	616.2 ft.	616.8 ft.	617.8 ft.	618.5 ft.	619.3 ft.

The long term trends of degradation of tail water levels (minimum) for discharge of 300,000, 400,000, 500,000 and 600,000 cusecs are shown in Figure 3 (a,b,c,d). It may be observed that there was spectacular degradation in the initial years, but it seems to have been slowed down now.

It is recommended that river cross section may be periodically observed at 1 km interval up to 25 km distance downstream of barrage to understand the state of riverbed degradation which is resulting in tail water lowering. In addition, a mathematical modeling study for riverbed changes below Chashma Barrage should also be carried out to predict future river behavior.



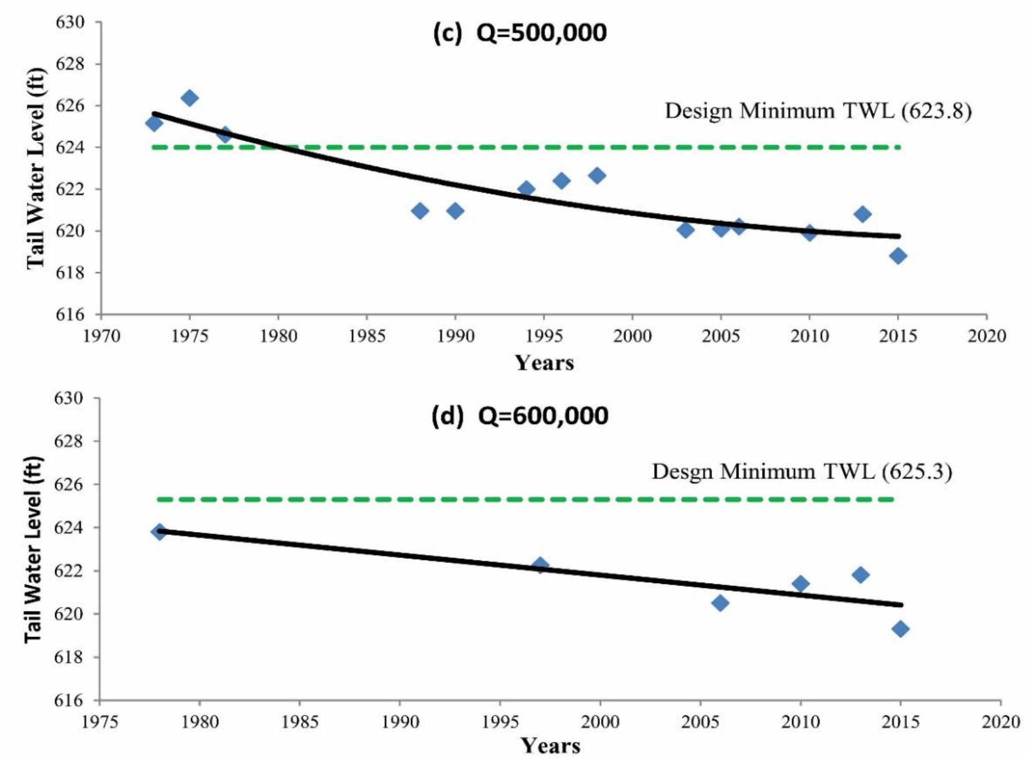


Figure 3: (a,b,c&d) Degradation Trends of Tail Water Levels at various Discharges

4.2 Jump Formation and Energy Dissipation in the Stilling Basin

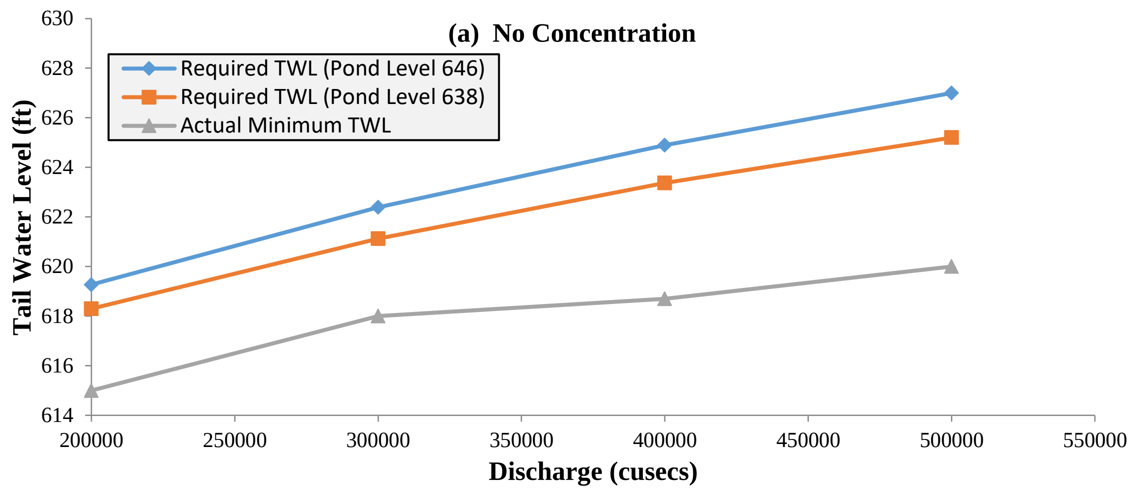
The high rate of retrogression was a serious concern even during the early years of barrage operation, as it affected the performance of stilling basin and its safety. These two cases have been analyzed, using upstream energy levels with existing retrogressed water levels. For the 950,000 cusecs discharge, the existing tail water level has been found short by 6.23 ft. for standard bays, and 6.27 ft. short in under sluice bays, considering both pier effect and 20 % flow concentration. For 500,000 cusecs discharge, the tail water level is short by 4.07 ft. in standard bays and 4.58 ft. for under sluice bays as indicated in Table 2. These values represent 15 to 23 percent of the required depth for jump formation and are no more small values to be ignored. In fact, the existing tail water depths are insufficient to form proper jump and one could, at the best, expect only partial or incomplete jump formation with inadequate energy dissipation. A strong tendency of sweep-out of jump from the stilling basin is indicated. High velocity currents emerging out of stilling basin are likely to continue eroding the riverbed and tail water lowering. No wonder the degradation trends of tail water are continuing, though at decreased rate, even after 45 years of commissioning of barrage.

Table 2: Adequacy of Exiting Tail Water Levels for Jump Formation

Description	**Discharge 950,000 cusec**				**Discharge 500,000 cusec**	
	Standard Bays		Under-sluice Bays		Standard Bays	Under sluice Bays
Upstream Energy Level (ft.)	641.4		641.4		634.2	634.2
Discharge Distribution (cusec)	690,000		260,000		346,000	154,000
Pier Effect	Yes	Yes	Yes	Yes	Yes	Yes
20% Flow Concentration	No	Yes	No	Yes	Yes	Yes

Discharge Intensity at glacis ft^2/sec.	280.5	336.6	393.9	472.7	168.78	280
Required tail water depth, ft.	24.97	26.63	29.88	31.67	18.77	24.28
Existing Tail water depth, ft.	20.40	20.40	25.40	25,40	14.70	19.70
Deficiency (-) of tail water depth ft.	-4.57	-6.23	-4.48	-6.27	-4.07	-4.58
Deficiency of tail water depth (%)	18.3	23.4	15.0	19.8	21.7	18.9

It should be pointed out that if water is passed at higher upstream pond levels with gated operation, the problem of insufficiency of tail water will be severer, and will be felt even at lower discharges, as shown in Figure 4 (a & b). Therefore, it is stressed that flood flows should be discharged through the barrage at the lowest possible pond level.



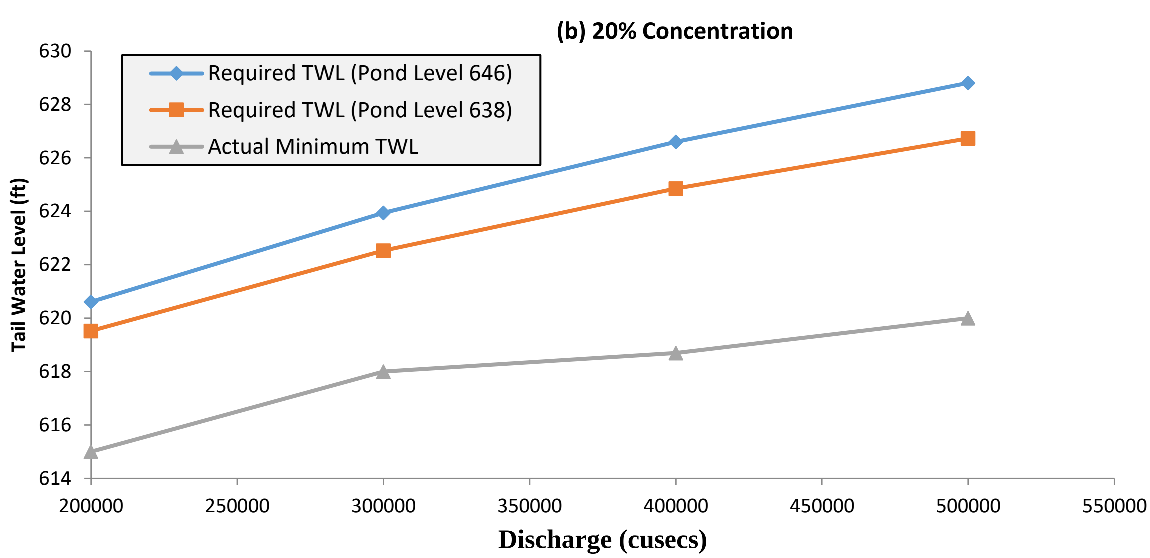


Figure 4: Comparison of Required and Existing Tail Water Levels (TWL) for various Discharges Passed at Different Pond Levels

5 CONCLUSIONS

It is now necessary to find a permanent solution to the unsatisfactory performance of stilling basin, to minimize the recurring damages to apron areas, and to neutralize the riverbed degradation due to release of un-dissipated energy and high velocity currents below the barrage. The available options are:

(i) *Deepening the Stilling Basin:* If the stilling basin was to be re-designed, its floor will have to be set at considerably lower level to provide the required conjugate depth in accordance with existing tail water conditions. This will require dismantling of existing floor, impact blocks, baffle blocks and concrete blocks over the inverted filter and relaying the same. This option will not be cost effective, difficult to implement and does not appear to be feasible, hence not recommended.

(ii) *Construction of a secondary weir:* This option with appropriate crest level and distance from existing Barrage center line tested on computer and thereafter suitable scale hydraulic model, would enable the required tail water level to be maintained for jump formation and energy dissipation, reduce damages to impact blocks, and concrete blocks and stone apron areas. It will also relax the restriction of adherence to 40 ft. head across limit and thus permit relatively higher pond levels to be maintained for increased energy generation.

(iii) *Construction of a second stage (or auxiliary) stilling basin:* Under this option a second stage stilling basin would be constructed below the existing stilling basin; the two stilling basins will jointly kill the energy of water and release it in tranquil manner to the river below. Its crest would be set at relatively lower level as it is not intended to raise the tail water levels because the function of killing the remaining energy (undissipated energy) will be performed by the second stage stilling basin.

To find an appropriate solution to the problem, it is recommended that a detailed study for remedial measures to improve performance of stilling basin, for options (ii) and (iii) may be initiated

REFERENCES

[1] D. Valero, D. B. Bung, B. M. Crookston, and J. Matos, "Numerical investigation of USBR type III stilling basin performance downstream of smooth and stepped spillways," in 6th International Symposium on Hydraulic Structures: Hydraulic Structures and Water System Management, ISHS 2016, 2016, pp. 635–646, doi: 10.15142/T340628160853.

[2] H. Babaali, A. Shamsai, and H. Vosoughifar, "Computational Modeling of the Hydraulic Jump in the Stilling Basin with Convergence Walls Using CFD Codes," Arab. J. Sci. Eng., vol. 40, no. 2, pp. 381–395, Dec. 2015, doi: 10.1007/s13369-014-1466-z.

[3] Q. H. Jalut and N. F. El-Baaja, "Experimental Study for Energy Dissipation Using Stilling Basin With One and Two Consecutive Blocks," Diyala J. Eng. Sci. Eng. Sci., vol. 7, no. 2, pp. 61–82, 2014.

[4] N. Rajaratnam and K. I. Hurtig, "Screen-Type Energy Dissipator for Hydraulic Structures," J. Hydraul. Eng., vol. 126, no. 4, pp. 310–312, Apr. 2000, doi: 10.1061/(ASCE)0733-9429(2000)126:4(310).

[5] "Basic Parameters for Design," in Developments in Geotechnical Engineering, vol. 37, no. C, Elsevier, 1985, pp. 28–393.

[6] S. Barjastehmaleki, V. Fiorotto, and E. Caroni, "Spillway Stilling Basins Lining Design via Taylor Hypothesis," J. Hydraul. Eng., vol. 142, no. 6, p. 04016010, Jun. 2016, doi: 10.1061/(ASCE)HY.1943-7900.0001133.

[7] Y. Kim, G. Choi, H. Park, and S. Byeon, "Hydraulic jump and energy dissipation with sluice gate," Water (Switzerland), vol. 7, no. 9, pp. 5115–5133, 2015, doi: 10.3390/w7095115.

[8] S. Jüstrich, M. Pfister, and A. J. Schleiss, "Mobile Riverbed Scour Downstream of a Piano Key Weir," J. Hydraul. Eng., vol. 142, no. 11, p. 04016043, Nov. 2016, doi: 10.1061/(ASCE)HY.1943-7900.0001189.

[9] M. Ben Meftah, F. De Serio, D. De Padova, and M. Mossa, "Hydrodynamic structure with scour hole downstream

of bed sills," Water (Switzerland), vol. 12, no. 1, 2020, doi: 10.3390/w12010186.

[10] R. F. Carvalho, C. M. Lemos, and C. M. Ramos, "Numerical computation of the flow in hydraulic jump stilling basins," J. Hydraul. Res., vol. 46, no. 6, pp. 739–752, Nov. 2008, doi: 10.1080/00221686.2008.9521919.

[11] F. S. F. Abdelhaleem, "Effect of semi-circular baffle blocks on local scour downstream clear-overfall weirs," Ain Shams Eng. J., vol. 4, no. 4, pp. 675–684, Dec. 2013, doi: 10.1016/j.asej.2013.03.003.

THE CHINIOT DAM – SHEET PILE DESIGN ASPECT

[a] Ijaz Ahmad
a: Centre of Excellence in Water Resources Engineering, University of Engineering and Technology, Lahore 54890, Pakistan,
dr.ijaz@uet.edu.pk

Abstract- The hydraulic structures can be built on either of permeable or impermeable foundations. The structures built on permeable foundations are subject to seepage pressures and the optimal cost of these structures is a non-linear function of the factors that cause the seepage force under the structure. However, the basic parameters of hydraulic structure, such as the depth of sheet piles or cut edges, and the length and thickness of the floor, cannot be determined in a cost-effective manner. In designing hydraulic structures, sheet piles are needed to reduce uplift force and hydraulic gradient. Usually, two sheet piles are required. The upper pile is used to reduce the uplift force, and the d/s pile is used to reduce the hydraulic gradient. The results show that if the d/s pile is deeper than the upper cutting wall, the resulting lifting force will increase. The increase in the depth of the d/s pile and the increase in the overall length of the floor result in a decrease in the resulting hydraulic gradient. When the two piles meet at the end of the hydraulic structure, the exit is lower than when the pile in the d/s direction is larger. On the other hand, the obtained results provide the best optimal parameters in terms of seepage flow, length and floor thickness. Use safe exit gradient and filters, respectively to incorporate soil type and hydrological conditions into the dam design.

Keywords- Chiniot Barrage; Chiniot River; Sheet Pile; Khosla Theory

1 INTRODUCTION

The surface water in Pakistan is the perennial influx from the Indus River and its tributaries (i.e., the Jerum River and the Chana River). Though, the flow of these rivers varies greatly from year to year and seasonally. Approximately 84% of river flows occurs in the summer months (April, May, and June), and due to a lack of available storage capacity, a significant portion of this discharge flows into Arabian Sea unused. Conversely, there is an urgent need to develop available water resources to sustain irrigated agriculture, which uses about 97% of the available river flows. Therefore, previous developments in the related water and hydroelectric power sectors suggested establishing a surface water storage plan through dam construction, to retain excess river flow for use when river flow is low and use the hydraulic head for power generation.

Warsak was the first dam built on the Kabul River in 1960. Its height is approximately 76 m and it created a small storage with an initial capacity of 493 Mm^3. The construction of the dam helped in the development of irrigated agriculture and created an additional power generation capacity of 240-megawatt. On the other hand, due to excessive sedimentation, the storage capacity of 18,784 Mm^3 built in Mangla, Tabela and Chashma continues to decrease. The loss of storage capacity of approximately 5,884 Mm^3 requires urgent replacement. Studies have been conducted at the 7,894 Mm^3 Diamer Basha Dam and the 7,400 Mm^3 Akhori Dam to use the remaining flow from the Indus River. Similarly, Mangla Dam Project have been raised for additional storage of 3,454 Mm^3 on Jhelum River. However, a storage on Chenab River is also required to store flood flows to be used in low flow seasons. The historical record it is evident that Chenab River huge floods which inundate adjoining areas near the Chiniot town for which British Govt constructed a dike about 4 to 5 km from the river to avoid submergence of villages in early 19th century. However later on, people have established several villages in and around the dyke which led to displacement during high flood season causing loss of lives and properties. The flood discharge also goes waste without utilization for the agriculture.

Tariq [1] studied the expected annual damage for the Chenab River floodplain using the multidirectional conjunctive approach to analyse the different measures to avoid extensive damage. Iqbal [2] and Hyder and Iqbal [3] worked upon the damages to household and agricultural land in Chiniot District and their coping mechanisms and found that the households are very exposed to flood in 2014 and even with the seventy percent of the area being warned of the floods, the citizens were unable to avoid the damages the were to come with the flood. Tariq [4] worked upon optimization of management measures for the floods in Pakistan and came with something similar to a guideline for managers to use available resources to their advantage and reduce the flood plain. The concept of the creep length for the flow under hydraulic structure was introduced by the Bligh [5]. The creep length was defined as the path of the seepage line which is in contact with the hydraulic structure. The Bligh theory assumed that hydraulic gradient remains constant along creep length. According to the theory the uplift pressure is linear as it varies linearly with the creep length due the linear energy loss along the creep length. The weighted theory of creep length was introduced by Lane [6] after investigating over 200 damaged hydraulic structures. According to the theory the horizontal creep length is different as compared to vertical creep length. The theory assigned the coefficients of 0.33 and 1.0 for total horizontal and vertical creep length respectively. Another method to estimate the distribution of the uplift pressure was presented by Khosla and Bose [7] using schwarz-christofel transformation method for weir design and for flat foundation type. Analytical solution for finite-depth seepage for following two cases was presented by Pavlovsky [8], [9]: flat aprons with single cut-off and depressed floors without cut off. In another research by Koupaei [10], it was stated that the quantum of uplift pressure determined by using Lane and Bligh is less than Khosla.

Salmasi et al. [11] employed relief wells below the dam to reduce the lifting force. These wells collect seeping water from the bottom of the dam, thereby preventing the formation of excess pore pressure. This helps to stop the piping phenomenon at the emerging d/s end of the dam. Some researchers use semi-impermeable blankets to counter the lifting force and seepage [12]. Usually, the blanket is made of compressed clay and will increase the creep length. This leads to more energy loss compared to the case where there is no blanket on top of the hydraulic structure. Nourani et al. [13] studied the best location for vertical drainage in a gravity dam. The finite element method (FEM) is used to predict the lifting force (U) of the vertical outlet based on the gravity dam. The design of irrigation canals can be considered from two perspectives: (1) the leakage of unlined ground channels; (2) the lifting force of lining channels [14]. Salmasi et al. [13] Reduced height by using longitudinal drain pipes with underlined channels. Jafari et al. [15] placed a filter housing around the drain pipe below the bottom of the concrete channel. This reduces the lifting force under the channel and extends the service life of the pipeline lining.

Shayan and Tokaldany [16] investigated that in the addition the seepage discharge due to increase in the seepage velocity increases the movement of soil particles which ultimately arises the phenomena of piping and undermining and the safety of the structure against the piping phenomena primarily depends upon the exit gradient while designing the structure. Novak et al. [17] found that seepage through the hydraulic structures should always be encountered the for the safety of structure. The construction of the cut off below the structure and on the flanks of if necessary, will control the seepage through the structure. The cut off can be formed by from wide trenches backfilled with clay or by drilling and grouting depending upon the type of soil strata. Ahmed and Bazaraa [18] attempted the calculation of water seepage through the hydraulic structure is generally evaluated through 2-dimensional (2D) analysis which is particularly suitable for cases where soil formation is homogenous, or the geometry is regular and subsequently it simplifies the problems.

It is evident from the above-mentioned studies that the selection of the correct parameters in the design of hydraulic structures plays pivotal role in the success of these projects. As of now, more than 14 hydraulic structures are proposed and/or under rehabilitation process in Punjab province. Therefore, present study aims to check the impact of high specific discharge on the length of pile sheets, scouring depth using Khosla theory which has been extensively used in subcontinent for the design of hydraulic structures on alluvial rivers.

2 STUDY AREA

Pakistan possesses a number of rivers (Figure 1). The Chenab river is formed at the confluence of the Bhaga and Chandra river. These two rivers joined each other at Tandi to form river Chenab. The highly elevated part of Chenab catchment is snow covered area located in the northeast part of the Himalayas. From Tandi to Ahnur, the river runs through the mountains. The river is 1,232 kilometers long and has a basin area of 41,760 square kilometers. The river enters Pakistan above Cape Mallard, and the slope changes very abruptly. The Chiniot Dam Project is located on Chenab River in Tehsil and District Chiniot, Faisalabad Division, Punjab at about 100 km downstream of Qadirabad Barrage and 5 km from the Chiniot city and about 100 meters upstream of existing Railway Bridge on Chenab River. The Chenab River at proposed dam/barrage site gets divided and then passes through narrow gorges. During floods, the narrow gorges obstruct the flow and create a backwater effect. Historical evidence reveals that when water levels are high, the flood water inundates a vast area (about 485 sq. km) upstream proposed dam site.

Figure 1: Location of Chiniot dam project on river Chenab

Chenab River is measured at Marala, which is located about 10 km below the Line of Control. Here it drains an area of about 29,560 km^2 and has an average annual inflow 31,703 Mm^3 (25.702 MAF) as shown in Figure 2.

During the months of November to February, the flow of the Chenab River at Marala is very low. During this period, India will be able to resolve the problems upstream of Marala Barrage (existing and proposed hydroelectric dams) and block the flow of 168.3 Mm^3 into the Chenab River for 21 days. If India takes advantage of its ability to manipulate upstream structures, something alarming may happen in future.

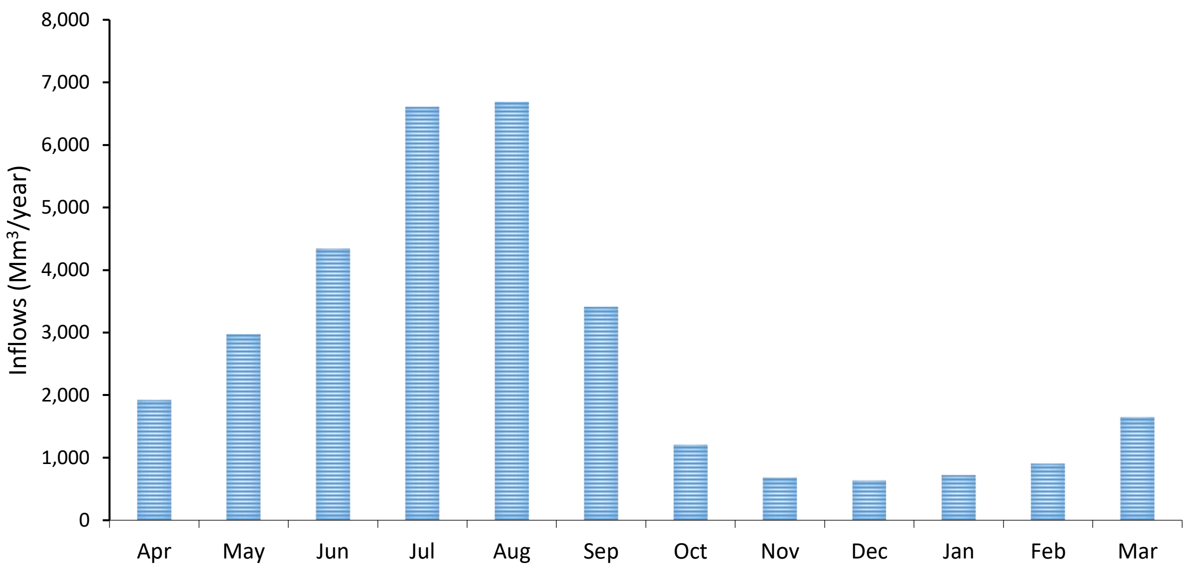


Figure 2: Mean monthly variations in inflows at Marala station of Chenab river (1976-2017)

3 RESEARCH METHODOLOGY

3.1 Waterway

Flood data was analysis and flood estimated for a return period was estimated using Gumbel Distribution. The flood value is in order of 35300 m^3/s. The bed level of the river at barrage site is 178m, the same adopted for the crest level under sluices and weir height of 1.5 m assumed.

Three considerations control the waterway of a hydraulic structure. They are a variety of designs, Lacey designed waterway and looseness factors. It is generally believed that by restricting waterways, the formation of shoal can be eliminated. However, although the length of the structure is short, this increases the discharge intensity, so the undersluice part becomes heavier as the height of the gate increases and the cost increases.

3.2 Lacey's Design Waterway

Lacey's wetted perimeter formula for estimating the waterway is given as follows:

$$P = 4.75\sqrt{Q} \qquad (1)$$

Where P is the Lacey's wetted perimeter and Q is the design discharge in cumecs (m^3/sec).

3.3 Looseness Factor

The ratio of the actual width to the calculated width is the "loosness factor", which is the third parameter that affects the width of the structure. The value used varies from 1.9 to 0.9, and the largest coefficient was used in the previous design. Usually, it ranges from 1.1 to 1.5. Judging from the performance of these structures, there is a feeling in some respects that when the looseness coefficient is high, it tends to form shoal in front of the structure, causing damage and maintenance problems. The consultant will use the most favorable looseness factor to provide reasonable flexibility while minimizing adverse effects.

3.4 Afflux

The maximum flood height in the river caused by dam construction is defined as Afflux. Although the flow is initially limited to a small section of the river when it rains, it gradually extends too far until the final slope of the river is formed at the source.

The minimum waterway was determined using lacey formula which is about 908 m long. From the computed value of lacy's waterway it appears that a minimum width required is 908 m. The width at barrage site need to be widened by cutting the gorge so that the designed flood could safely pass the barrage. From the site markings it is evident that whenever a flood of more than 700,000 cusecs occurred the entire areas on both banks of Chenab River submerged. The upstream total energy level calculated was 191.321 m. Keeping in view the total upstream energy level free board was adopted 4 m above the full reservoir level i.e. 193.5 masl with 20% retrogression. as the dykes are made of embankment overflow will damage entire reservoir.

3.5 Design for sheet piles

The calculations for seepages pressures for the design of sheet piles is done on the basis of Khosla theory which is an updated method compared to Lane's and Bligh's theory. The calculations are done for the pool level or no-flow condition as it results in the maximum head difference available for seepage.

First of all, the specific discharge is calculated by dividing the max. anticipated flood by the waterway obtained as above. Then the depth of piles is obtained using the scour depth (R) relation. The upstream pile depth is kept 1.25R and downstream pile depth is kept 1.5R.

$$R = 1.35\left(\frac{q^2}{f}\right)^{1/3} \qquad (2)$$

$$G_E = \frac{H}{d} \cdot \frac{1}{\pi\sqrt{\lambda}} \qquad (3)$$

Where, R is normal scour depth, q is the discharge intensity between two piers and f is silt factor, G_E is the exit gradient, H is the maximum seepage head across the structure, d is the depth of downstream sheet pile, value of $\frac{1}{\pi\sqrt{\lambda}}$ can be read out from blench curves corresponding to values of b/d and b represent is the total floor length.

The pressures are calculated using blench curves and then the corrections are applied where necessary based upon interference of piles, thickness of floor and slope of the floor. And after all this, the exit gradient is checked to be in safe limits for the design to be considered safe.

4 RESULTS

For the design of Chiniot dam for a flow of 35,354 m^3/s, Khosla's traditional two-dimensional seepage method was adopted. The pile depth of this method is limited to detailed considerations and the floor length is determined to achieve the allowable safe exit gradient. The undersluice is designed for high floods. The length of the stilling basin is 39 m. The safe exit gradient 1:6 depends on the type of soil on which the dam is based. The length of downstream cutoff wall of 22.6 m is about twice the length of upstream cutoff wall of 11 m. The design of the floor length upstream and downstream takes into account the slope of the safe exit gradient, and the nominal thickness of the floor is required on the upstream side of barrage, and the lifting pressure is balanced on the upstream side of the ponding water. However, the minimum thickness of the upstream floor should be 1 m, and the thickness of the floor should be 1.0 m along the floor and 1.5 m lower than the top.

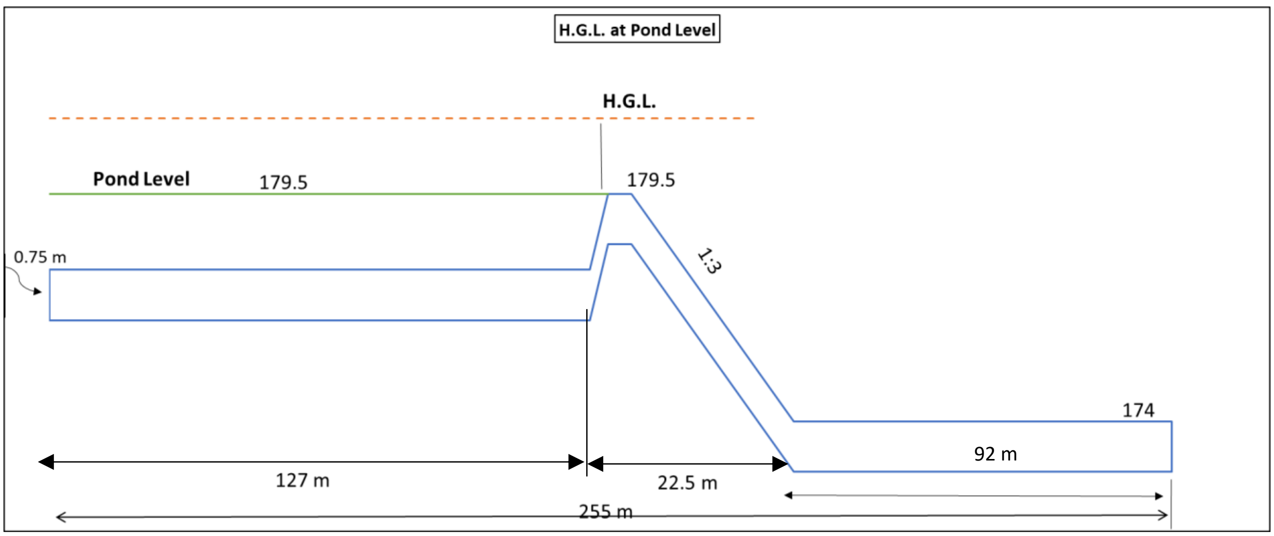


Figure 3: Cross-sectional view of Chiniot barrage

However, the downstream thickness should be evaluated from the nominal thickness of the entire length of the floor. In the past (in the mid-19th century), barrages were designed and built in India based on the experience of the time. Some of them are based on Bligh's slip theory, which proved to be unsafe and expensive.

Table 1 U/S and D/S Pressure calculation summary

Condition	D/S water level	U/S water level	Head	Elevasi of Sub Soil High Line Above Datum					
				Upstream Pipeline			Downstream Pipeline		
				ΦE_1	ΦD_1	ΦC_1	ΦE	ΦD	ΦC
	m	m	m	100	81.6	73.88	27.40	19	0
No				5.86	4.78	4.33	1.61	1.11	0
Flow	182.14	188	5.86	188	186.92	186.47	183.75	183.26	182.14
High				1.50	1.22	1.11	0.41	0.29	0

Flood	189.5	191	1.50	191	190.72	190.61	189.91	189.79	189.50

The upstream and downstream protection works are also designed by using empirical and convectional formulas. Considering the economic and other related factors block protection is adopted for the protection works.

From the calculation the scour depth about 31m which is significantly high values and the RL of bottom of sheet pile is 158 m. From scour depth there are significant chances that both upstream and downstream piles will have effect on each other. The uplift forces are prominent and requires huge protective measures to avoid any catastrophic failure of barrage. Moreover, model study is required to be undertaken for such a high scour depth and pile sheets. As it was already expected from long piles sheets that a comparatively longer floor length will be required to increase the seepage and losses beneath the structure so that exist gradient will be zero and pressure at downstream pile C2 must be zero. A middle pile is also required to reduce the effect of unbalanced head at the toe of glacis.

5 CONCLUSION

Following conclusions can be drawn from the conducted study:

The present work shows that the design of Chiniot dam on impermeable foundations is economical and safe under conditions of infiltration and increased water pressure. Barrage design uses a traditional approach. The results obtained provide the best barrage parameters, including upstream and downstream sheet piles / cross-section depth, floor length and thickness. Soil type and hydrological conditions are combined in the design of the dams through the safety outlet slope and the seepage head respectively. The conclusions of this study can be summarized as follows.

- Compared with downstream pile and total length of floor, the upstream pile depth is less sensitive to the SGE value or the head of the leakage.
- The assumed minimum floor thickness will affect the design parameters and hence the total cost of the dam from practical considerations, the nominal value is crucial to reduce the overall cost of dam.
- As the head of seepage increases, the depth of the d/s piles and the length of the bottom plate increases. Deep d/s piles can cause excessive water build-up in the barrage. Therefore, the upper limit of the sheet pile depth must be set to reduce the degree of pondage in the barrage, while the overall cost is not excessively increased.

REFERENCES

[1] M. A. U. R. Tariq, "Risk-based flood zoning employing expected annual damages: The Chenab River case study," Stoch. Environ. Res. Risk Assess., vol. 27, no. 8, pp. 1957–1966, Dec. 2013, doi: 10.1007/s00477-013-0730-1.

[2] N. Iqbal, "Households Losses in 2014 Floods and Coping Strategies A Study of Chiniot , Punjab Pakistan Institute of Development Economics Islamabad," *pide.org.pk*, 2015.

[3] A. Hyder and N. Iqbal, "Socio-economic losses of flood and household's coping strategies: Evidence from flood prone district of Pakistan," *PIDE Work. Pap.*, vol. 1, no. 142, 2016.

[4] M. A. U. R. Tariq, *Risk-based planning and optimization of flood management measures in developing countries-Case Pakistan*. VSSD, 2011.

[5] W. G. Bligh, "Dams, barrages and weirs on porous foundations," *Eng. News*, 1910.

[6] E. W. Lane, "Security from underseepage- masonry dams on earth foundations," *Trans. Am. Soc. Civ. Eng.*, vol. 100, pp. 1235–1272, 1935.

[7] E. M. AN Khosla, NK Bose, *Design of weirs on pervious foundations*. Publication number 12 of the Central Board of Irrigation, Simla, India, 1936.

[8] N. N. Pavlovsky, "The theory of ground water flow beneath hydrotechnical structures," *Res. Melior. Institute, Petrograd, USSR.*, 1922.

[9] N. N. Pavlovsky, "Collected works, Izd," *AN SSSR Moscow–Leningrad, USSR.*, 1956.

[10] J. A. Koupaei, "Investigation of the effective elements on uplift pressure upon diversion dams by using finite difference," University of Tarbiat Modarres, Tehran, Iran., 1991.

[11] F. Salmasi, B. Mansuri, and Raoufi, "Use of Numerical Simulation to Measure the Effect of Relief Wells for

Decreasing Uplift in a Homogeneous Earth Dam," *Civ. Eng. Infrastructures J.*, vol. 48, no. 1, pp. 35–45, Jun. 2015, Accessed: Aug. 06, 2020. [Online]. Available: https://ceij.ut.ac.ir/article_53706.html.

[12] F. Salmasi and M. Nouri, "Effect of upstream semi-impervious blanket of embankment dams on seepage," *ISH J. Hydraul. Eng.*, vol. 25, no. 2, pp. 143–152, May 2019, doi: 10.1080/09715010.2017.1381862.

[13] B. Nourani, F. Salmasi, A. Abbaspour, and B. Oghati Bakhshayesh, "Numerical Investigation of the Optimum Location for Vertical Drains in Gravity Dams," *Geotech. Geol. Eng.*, vol. 35, no. 2, pp. 799–808, Apr. 2017, doi: 10.1007/s10706-016-0144-1.

[14] R. Hosseinzadeh Asl, F. Salmasi, and H. Arvanaghi, "Numerical investigation on geometric configurations affecting seepage from unlined earthen channels and the comparison with field measurements," *Eng. Appl. Comput. Fluid Mech.*, vol. 14, no. 1, pp. 236–253, Jan. 2020, doi: 10.1080/19942060.2019.1706639.

[15] F. Jafari, F. Salmasi, and J. Abraham, "Numerical investigation of granular filter under the bed of a canal," *Appl. Water Sci.*, vol. 9, no. 5, p. 3, Jul. 2019, doi: 10.1007/s13201-019-1023-8.

[16] H. Khalili Shayan and E. Amiri-Tokaldany, "Effects of blanket, drains, and cutoff wall on reducing uplift pressure, seepage, and exit gradient under hydraulic structures," *Int. J. Civ. Eng.*, vol. 13, no. 4, pp. 486–500, Dec. 2015, doi: 10.22068/IJCE.13.4.486.

[17] P. Novak *et al.*, *Hydraulic Structures, Fourth Edition*. CRC Press, 2018.

[18] A. A. Ahmed and A. S. Bazaraa, "Three-Dimensional Analysis of Seepage below and around Hydraulic Structures," *J. Hydrol. Eng.*, vol. 14, no. 3, pp. 243–247, Mar. 2009, doi: 10.1061/(asce)1084-0699(2009)14:3(243).

PROVISION OF SUBSIDIARY WEIR AS A SOLUTION FOR DAMAGES CAUSED BY RETROGRESSION AT JINNAH BARRAGE

[a] Ijaz Ahmad, [b] Faraz-ul-Haq
a: Centre of Excellence in Water Resources Engineering, University of Engineering and Technology, Lahore 54890, Pakistan, dr.ijaz@uet.edu.pk
b: Centre of Excellence in Water Resources Engineering, University of Engineering and Technology, Lahore 54890, Pakistan, engrfaraz@uet.edu.pk

Abstract- The process of retrogression initiates temporary soon after the construction of hydraulic structures on the alluvial rivers. Retrogression resulted in unusually high speeds downstream of the barrage, resulting in repeated structural damage to friction blocks, reverse filter blocks, and stone apron. Operational problems of sluice gates and hoists. The main objectives of this research work are to study how damages were controlled caused by Retrogression and to check different discharges with their effects of D/S for safety. The hydraulic performance was checked for different flows starting from 20,000 cfs. In first case no additional retrogression was considered with 20% flow concentration. In second case 3ft additional retrogression was considered due to Kalabagh dam and 20% flow concentration. The results indicate that the lowest jump formation level with Blench equation with 20 % concentration of flow and additional 3 feet retrogression downstream of the proposed weir is at RL660.28. Maximum water level downstream of Barrage in main weir portion is RL693.14. Moreover, subsidiary weir provided will stop downstream erosion of barrage.

Keywords- Subsidiary Weir, Retrogression, Jinnah Barrage, Discharge

1 INTRODUCTION

Agriculture is the backbone of Pakistan. It represents 21% of the GDP and represents, with agri-food products, 80% of the total export revenues of the country. More than 48% of the workforce is involved in this sector. Most of Pakistan's area is in an arid and semi-arid zone. This leads to overcoming the water needs for agriculture through irrigation as rainfall is not sufficient. Pakistan's irrigation system is the largest integrated irrigation system in the world, serving about 18 million hectares of cultivated land. There are 3 large storage tanks, 19 dams, 12 inter-river linkage channels, 45 independent irrigation canals and more than 140,000 watercourses.

Dam is an artificial barrier across a river to stop floods, assist with irrigation or navigation, or to generate electricity by tidal power. A weir / dam is an important structure used to divert water from the river through a canal system for irrigation and other useful purposes. If the difference between the pond level and the peak level is less than 1.5 m, the level of the pond can be maintained by means of roller shutters. However, if the difference is greater than 1.5 m, a weir controlled by a door is necessary, what is called a "Barrage". It is designed based on surface flow and subsurface.

The downstream riverbed was lowered due to retrogression. The barrage was unsafe and could have caused partial or total failure. Retrogression resulted in unusually high speeds downstream of the barrage, resulting in repeated structural damage to friction blocks, reverse filter blocks, and stone apron. Operational problems of sluice gates and hoists.

Ali et al. [1] investigated the impacts of varied spaced corrugated decks on downstream local scouring due to the formation of submerged jump, keeping the Froude number between 1.68 and 9.29. A case of flat aprons was considered to evaluate the impact of corrugated decks on scour hole dimensions. The results showed that the triangular corrugated decks minimize the depth of scour and the length of fine sand in average percentage of 63.4% and 30.2%, respectively and 44.2% and

20.6%, respectively. It was also concluded that the use of corrugated decks downstream of the hydraulic structures is an effective technical approach to minimize the area of the scour holes.

Chaudhry et al. [2] evaluated efficacy of downstream energy dissipation system and capacity of Taunsa Dam in pre-construction and post-construction underwater weir scenarios. They concluded that the presence of sub-dam downstream of the Taunsa Dam was not beneficial and the real cause of the damage in the plenum was the poor quality of the concrete; rather than variations in the level of the tail water. Chaudhry [3] reviewed previous studies / investigations, energy dissipation mechanisms, hydrographic surveys, soundings and soundings to estimate the damage and its cause and have concluded that at higher flow rates (> 0.5 Million cusecs), prevailing water level conditions becomes greater than the limit values (9 FPS) which trigger the displacement of the loose stone deck. The downstream speed became 12.2ft / sec (35.6% higher than critical limit) during the super flood of the year 1992 (842000 cusec) at the dam section which aggravated the displacement of the loose stone deck.

Hamidifar et al. [4] studied local scouring downstream of a rigid deck using a bed sill and investigated the effectiveness of scour reduction with a single downstream threshold. of the apron and evaluated its effectiveness at different distances. the end of the apron. As a result, they determined that the maximum scour downstream of the apron reduces up to 95%. In addition, variations in the characteristic lengths of the scour hole have been studied. In addition, it has been observed that completely buried thresholds may not be useful.

Khassaf et al. [5] computed depth of local scour around bridge pier using downstream bed sill (sand) as a countermeasure in the laboratory. A circular section pier model was used with clear water flow condition. They investigated three different size of pier diameter with four different water depths and four different flow velocities. As a result, they analyzed that the usage of sill as a countermeasure structure has a beneficial reduction of scour around pier around 25% for flow intensity 0.95 and the increasing diameter of pier with bed sill was given increasing scour depth. Hamidifar et al. [6] provided the most effective solution for bed protection downstream of hydraulic structures to investigate the usefulness of two countermeasures, i.e., bed sill and riprap - to decrease the scour depth adjacent to horizontal rigid decks. They concluded that upstream rip rap is proposed as an alternative method for protecting an erodible bed downstream of an apron.

Imran et al. [7] evaluated the use of corrugated beds and rough beds to reduce jump length and sequential depth, and these two measurements showed a large amount of downstream energy dissipation. Compared to a smooth bed, the jump length and sequential depth are also greatly reduced. As a result, the use of corrugated beds and rough beds reduces the scour length and depth and the cost of installing a plenum. Moreover, it was found that applying corrugated beds and roughness always performs better than smooth beds. Sharma et al. [8] studied the Singapore dam built across the Tapi River (Gujarat). Since its construction, significant damage has been reported during the recent floods in 2013 and 2014, during which significant scouring and settlement of concrete blocks was observed, ultimately threatening the main spillway structure. Regression hydraulic jumping conditions have been found to have prevailed at lower flow rates (<4000 m3 / s for 60%) even beyond stone protection due to deficient tail water conditions, which were the main because of the first reach of the spillway.

Castillo et al. [9] investigated the construction of the Pat Cardenello dam, and the expected changes in the Pat river. To assess the stability and safety of the structure, the shape and size of the erosion produced downstream of the dam due to the action of landfills and exits were verified, and to study through three complementary procedures: the empirical formula and the prototype obtained in the model, semi-empirical method based on pressure fluctuations, erodibility index and simulation of fluid dynamics. This method led to the proposal of a pre-excavated sedimentation tank. The pool will produce an effective water mattress. In addition, this will reduce sedimentation due to excavation and material carried by the river, especially during tank washing operations. The previously excavated basin will also allow for a symmetrical and regular flow, thus reducing the risk of possible landslides. Dehghani et al. [10] noted that some deficiencies of the spillway can be resolved by combining with valves. A disadvantage of valves is that they retain floating materials, which can be resolved if combined with landfills. This type of flow, generally in the form of jets, can have considerable potential for hydraulic flushing on the downstream side of the structure. Form wash holes. The conceptual model of the confluent downstream flow field below the spillway and gate shows that there is an interaction between the spillway over the spillway and the spillway below the obstacle, and the scrub holes are alternately cut and filled. Local cleanup is formed downstream of the structure, and scrubbed sediment accumulates as a bump downstream of the cleanup hole.

Hassan [11] conducted experimental studies to study the dimensions of the scour hole downstream of the combined weir and gate structures. Twelve models have been designed and each model consists of a composite weir consisting of two geometric shapes and three types of rectangular, semi-circular and triangular shaped doors, where several factors have been studied to discover the effect of changing geometry. spillway and valve, discharge flowing in the channel and concluded that the maximum depth of the scour values was recorded in models with circular door compared to other models with rectangular and triangular doors. The size of the deposits changes with the depth of the scour hole where each time the depth of the hole is increased due to the free fall of water from the edge of the compound weir, the sediment deposition was more, while the flow through the door helps to remove these sediments and make the deposit form flatter.

Habib et al. [12] reported scouring the loose sand bed downstream of the hydraulic jump formed on a rigid deck. Different kinematic conditions are produced to study scour holes and their development. Experimental data are used to study the relationship between scour depth and deck length. Some photographic investigations are made to show the influence of the structure of the flow in the area of the jump roller and the characteristics of the turbulence at the end of the jump on the scrubbing process. It was concluded that scour depth decreased with increasing length of rigid deck. In addition, photographic research was performed showing the large-scale turbulence characteristics of the roll area. Periods of vortex pairing, and immigration were observed, which caused an oscillation of the toe location of the jump with a remarkable shift of broken swirls in the tail water. These processes are considered to be the main cause of the instability of sand particles downstream of the jump. The main objectives of this research work are to study how damages were controlled caused by Retrogression and to check different discharges with their effects of D/S for safety.

2 STUDY AREA

The Jinnah Barrage consists of 42 bays and two undersluice portions. Each of undersluice portion consisted of 7 bays, with a clear waterway of 18.3 m. The total barrage width is 1152.4 m, and the clear waterway width of 768.1 m and 128 m for the main weir and undersluice portions, respectively. The elevations crests of main weir and undersluice crests are EL206.81 and EL204.20, respectively. Whereas, upstream and downstream floor levels are EL205.72 and EL203.29, respectively. Two dividing walls, 106.7 m long, divided weir and sluice sections upstream of the weir. In the left and right sluices, two fish ladders are constructed along the dividing wall. Jinnah Barrage right and left sluices have a 6.1m wide navigation bay and sediment removal system, respectively. The barrage is designed for a design flood of 26725.6 cumecs; however, because of the provision of sufficient freeboard, flood of 30945.8 cumec can be passed safely. The normal pond water level is at EL210.9 and will be raised to EL211.5 to meet the Thal Canal remodeled capacity of 283.2 cumecs.

3 METHODOLOGY

3.1 Discharge Calculations for proposed Subsidiary Weir

Proposed subsidiary weir is designed as fully ungated weir using formula,

$$Q = C'.b.E^{1.5} \tag{1}$$

Where:
Q is the discharge over crest (cusecs); b is clear width of weir (ft) and E is u/s TEL – crest RL

Existing barrage is a gated structure and in its original design, the value of C=3.20 was used and is still being used for high flow conditions without considering the submergence ratio. For gated flow condition, when bottom level of gate is submerged C=0.81 is used for calculating discharge without considering the submergence ratio. For gated flow condition, when downstream water levels are below bottom level of gate C=3.20 is used for calculating discharge without considering the submergence ratio. Coode & Partners, the designers of various barrages under IBP including Marala and Qadirabad followed Gibson method and used the submergence ratio for calculating the discharge. The parameters of new Khanki Barrage are also fixed using Gibson formula.In the case of submergence, the free flow discharge coefficient (C=3.8) is multiplied by a reduction factor C'/C.

Table 1: Values of reduction factor

h /E	C '/ C	C '
0.4	0.96	3.65
0.5	0.94	3.57
0.6	0.91	3.46

0.7	0.86	3.27
0.8	0.78	2.96
0.9	0.62	2.36
0.95	0.44	1.67

3.2 Equations used for different Design parameters

i) Discharge (Q) = ft^3/sec

It is the volume metric flow of water during per unit time.

ii) Discharge Intensity (q) = $ft^3/sec/ft$

Discharge flowing through per unit width of a structure which is;

$$q = Q/B \tag{2}$$

$$q = 1.70E^{3/2} \tag{3}$$

iii) Velocity of Approach

The velocity of flowing water approaching to a metering section is called velocity of approach which is;

$$H_{ap} = V^2/2g \tag{4}$$

iii) Energy Line (E)

It is equal to depth of water + velocity of approach.

$$E = Y + H_{ap} \tag{5}$$

iv) Lose of Head

Head lose is equal to U/S Total Energy Line – D/S Total Energy Line, HL = TUEL – TDEL

v) Critical Depth (dc)

It is the depth of water at which Specific Energy is minimum.

$$d_c = [q^2/g]^{1/3} \tag{6}$$

vi) Scour Depth (R)

It is the maximum depth measured from the High Flood Level (HFL) to the lowest bed point which is eroded/ scoured as an outcome of water current.

$$R = 1.35(q^2/f)^{1/3} \tag{7}$$

vii) Wetted Parameter (P)

It is the surface area of any cross section which is wetted by the flowing water.

$$P = 4.75\sqrt{Q} \tag{8}$$

Where P is the wetted perimeter and is given as B + 2D.

For rivers 'D' is negligible comparing to 'B' therefore P = B,

hence B = 4.75 √Q

viii) Conjugate Depth (d_1, d_2)

These are the depth of water it is before and after the formation of Hydraulic jump.

4 RESULTS AND DISCUSSIONS

The subsidiary weir at 600ft from the gate center line of main barrage is constructed only for weir section of the barrage.

4.1 Surface and subsurface flow analysis

The main weir is designed for the discharge of 950,000cusec; however, the hydraulic performance was checked for different flows starting from 20,000 cfs. In first case no additional retrogression was considered with 20% flow concentration. In second case 3ft additional retrogression was considered due to Kalabagh dam and 20% flow concentration. The water surface profiles formed due to both cases are shown in Figure 1 and Figure 2.

a. Case-1: No additional retrogression but 20% flow concentration

In case 1, additional retrogression was not provided; however, 20% flow concentration was assumed to counter the possibility of cross currents which may be hazardous to weir and caused excessive erosion. Water surface profile formed in this case is presented in Figure 1. It is clear that a smooth transition from super critical flow to sub critical flow with very small undulations was produced, the reason behind this is the non-presence of retrogression phenomenon as erosion is not taking place. Moreover, the jump is formed above the toe of glacis which is making it an acceptable scenario; however, retrogression was not considered in this case which is not possible in when hydraulic structures were constructed on alluvial rivers.

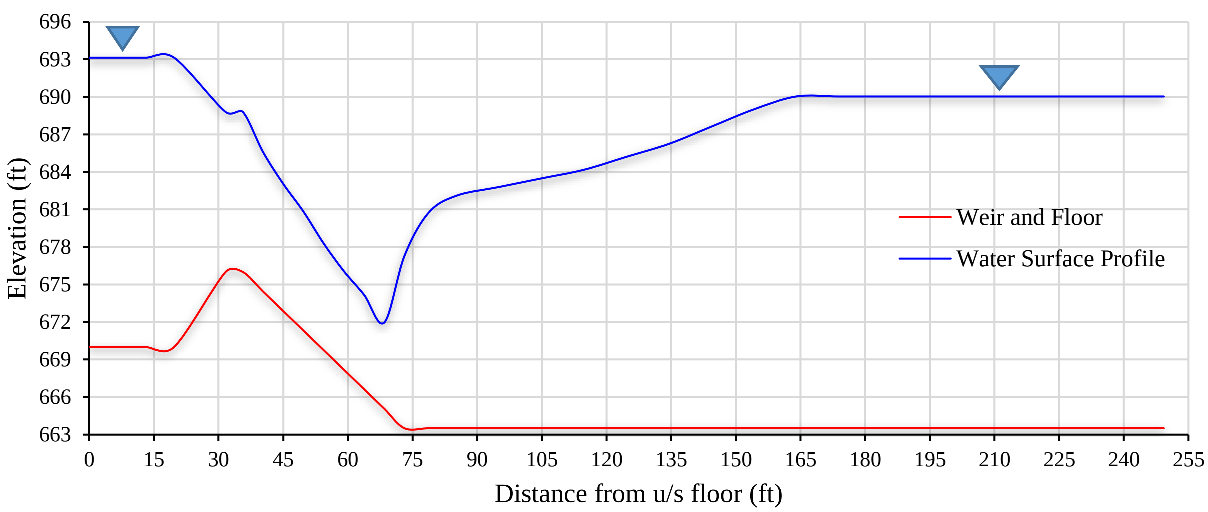


Figure 1: Water Surface Profile for No retrogression

b. Case-2: 3ft additional retrogression due to Kalabagh dam and 20% flow concentration

In this case, 3 ft additional retrogression was considered along with 20% flow concentration due to the Kalabagh dam. Water surface profile for this case is shown in Figure 2. Contrary to previous case when no retrogression was considered, a very rough transition from super critical flow to sub critical flow produced accompanied with large undulations. The major reason behind this is the occurrence of retrogression phenomenon. Due to erosion, velocities on d/s will increase and resultantly Froude's number will become greater and it will rise eddies formation from bed to surface. Therefore, subsidiary weir fixed with crest elevation at EL676 was proposed in physical sectional model. The slopes of the upstream and downstream glacis were designed to be 1V: 2H and 1V: 3H, respectively. Given that the Kalabagh Dam may have an additional 1 m retrogression after construction, the ground height of the water retention basin is set at EL659. The existing dam structure, including the concrete block floors, must be kept intact. The main weir and undersluice sections of subsidiary weir must be divided by extending the existing downstream dividing wall.

The study revealed that the energy dissipation system at Jinnah Barrage is impact/jump type. Conduction of subsidiary weir at Taunsa barrage has proven its efficiency by passing 973,000 cusecs discharge during the extreme flood event of 2010; therefore, the option of providing subsidiary weir downstream of hydraulic structures may considered after extensive physical and numerical model studies.

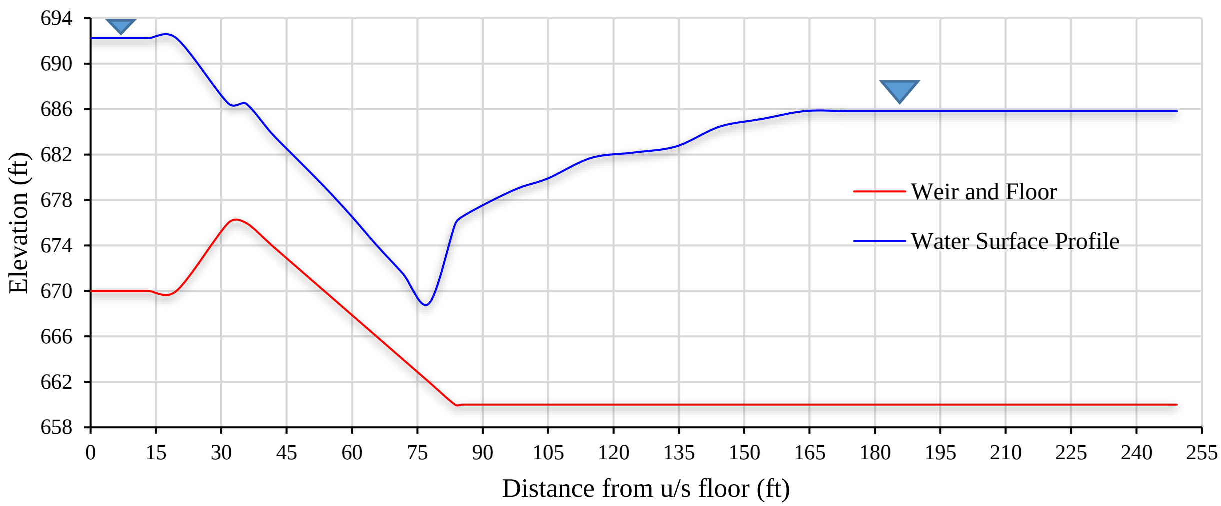


Figure 2: Water Surface Profile for 3ft retrogression

5 CONCLUSIONS

Major conclusions are given below:

- Subsidiary weir is check at different discharges for;
  - i. More than design discharge which caused the high afflux on U/S side which is not safe.
  - ii. Less than designed discharges upto 20,000 cumecs, which is safe and will not affect D/S designed parameters.
- The lowest jump formation level with Blench equation with 20 % concentration of flow and additional 3 feet retrogression downstream of the proposed weir is at RL660.28. So, the floor level fixed at RL 660.00 is Ok.
- Maximum water level downstream of Barrage in main weir portion is RL693.14.
- Subsidiary weir provided will stop downstream erosion of barrage.
- It is concluded that subsidiary weir may be a good option in reducing the retrogression effect and thereby minimizing the downstream floor damages. However, comprehensive physical numerical model studies should be performed for the better testing of the weir designed and to eliminate the effect of retrogression phenomenon under different conditions.

REFERENCES

[1] H. M. Ali, M. M. El Gendy, A. M. H. Mirdan, A. A. M. Ali, and F. S. F. Abdelhaleem, "Minimizing downstream scour due to submerged hydraulic jump using corrugated aprons," Ain Shams Eng. J., vol. 5, no. 4, pp. 1059–1069, Dec. 2014, doi: 10.1016/j.asej.2014.07.007.

[2] Z. A. Chaudary and M. K. Sarwar, "Rehabilitated Taunsa Barrage: Prospects and Concerns," *Sci. Technol. Dev.*, vol. 33, no. 3, pp. 127–131, 2014, Accessed: Jul. 20, 2020. [Online]. Available: https://www.std.com.pk/fulltext/?doi=std.2014.127.131.

[3] Z. A. Chaudhry, "Hydraulics of Jinnah Barrage; Existing Structure and Rehabilitation Alternatives," *Pakistan J. Eng. Appl. Sci.*, vol. 4, no. 0, pp. 66–73, Jun. 2009, Accessed: Jul. 20, 2020. [Online]. Available: https://journal.uet.edu.pk/ojs_old/index.php/pjeas/article/view/248.

[4] H. Hamidifar, M. Nasrabadi, and M. H. Omid, "Using a bed sill as a scour countermeasure downstream of an apron," *Ain Shams Eng. J.*, vol. 9, no. 4, pp. 1663–1669, Dec. 2018, doi: 10.1016/j.asej.2016.08.016.

[5] C. Grimaldi, R. Gaudio, F. Calomino, and A. H. Cardoso, "Control of Scour at Bridge Piers by a Downstream Bed Sill," *J. Hydraul. Eng.*, vol. 135, no. 1, pp. 13–21, Jan. 2009, doi: 10.1061/(ASCE)0733-9429(2009)135:1(13).

[6] H. Hamidifar, M. H. Omid, and M. Nasrabadi, "Reduction of scour using a combination of riprap and bed sill," *Proc. Inst. Civ. Eng. - Water Manag.*, vol. 171, no. 5, pp. 264–270, Oct. 2018, doi: 10.1680/jwama.16.00073.

[7] H. M. Imran and S. Akib, "A Review of Hydraulic Jump Properties in Different Channel Bed Conditions," *Life Sci. J.*, vol. 10, no. 2, pp. 126–130, 2013.

[8] P. J. Sharma, S. V. Chethan, P. V. Timbadiya, and P. L. Patel, "Identification of Causes of Failure of Downstream Block Protection for Singanpore Weir-Cum-Causeway, Surat," in *Development of Water Resources in India*, Springer, Cham, 2017, pp. 355–362.

[9] L. G. Castillo and J. M. Carrillo, "Characterization of the dynamic actions and scour estimation downstream of a dam," in *Dam Protections against Overtopping and Accidental Leakage - Proceedings of the 1st International Seminar on Dam Protections Against Overtopping and Accidental Leakage*, Mar. 2015, pp. 231–243, doi: 10.1201/b18292-26.

[10] A. A. Dehghani, H. Bashiri, M. Shahmirzadi, M. Ebrahim, and A. Ahadpour, "Experimental Investigation of Scouring in Downstream of Combined Flow over Weirs and below Gates," in *33rd IAHR Congress: Water Engineering for a Sustainable Environment*, 2009, pp. 3604–3609.

[11] F. A. Hassan, "The Effect of Flow Conditions and Geometric Parameters on the Scour Value Downstream Composite Structures of Weir and Gate," *Kufa J. Eng.*, vol. 7, no. 1, pp. 115–128, 2016.

[12] J. Farhoudi and K. V. H. Smith, "Profils de l'affouillement local a l'aval 'un ressaut hydraulique," *J. Hydraul. Res.*, vol. 23, no. 4, pp. 343–358, 1985, doi: 10.1080/00221688509499344.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

INVESTIGATING MULTIPLE DEBRIS IMPACT LOAD AND ROLE OF VEGETATION IN PROTECTION OF HOUSE MODEL DURING FLOODS

[a] Muhammad Asghar, [b] Ghufran Ahmed Pasha, [c] Usman Ghani, [d] Sohail Iqbal, [e] Muhammad Sohail Jameel
[a, b, c, d, e]Department of Civil Engineering, University of Engineering and Technology, Taxila, Pakistan,
asgharce10@gmail.com, ghufran.ahmed@uettaxila.edu.pk, usman.ghani@uettaxila.edu.pk,
sohailsakhani147@gmail.com, sohailjamil10@yahoo.com

Abstract- Storms and flooding caused significant damage to buildings. The waterborne debris created during such natural disasters will cause significant damage to the many structures unless they were designed for these loads. Flood field survey findings suggested large objects such as wooden logs, cars, vessels, storage barrels, and other containers intensify the damage. For this cause, a driftwood approach was established to test tree washout, floating trees movement, and collisions with the house model. This paper addressed the findings of experimental analysis on the frameworks to measure the debris impact, hydrostatic and hydrodynamic forces. It also analyzed the formulas, which were defined with the experiment results in the recently released design guidelines (FEMA P-646, 2012). Moreover different hydraulic jumps were observed while observing water surfaces in three different situations (without house model and vegetation, only vegetation and with vegetation and house model). This resulted in an energy reduction of up to 18 % for only vegetation case and 19 % for vegetation with house model.

Keywords-Experimental Modeling, Flood Born Debris, Floods, Flume Experiment, Vegetated Channel.

1 INTRODUCTION

Flood is often a huge volume of water overflowing outside of its normal parameters. Flood impacts can cause tremendous damage including buildings, properties, and human existence. Flood is the elevated volume of fluid (typically water) from a nearby body of water that saturates the ground which is typically dry throughout the year. Most frequent causes of inland flooding occur near a river or stream with intense rains over a watershed, either a reservoir or a levee breach, or snow covers in the northern areas rapidly melting. Flooding is often triggered by tsunamis or hurricanes which are known as tidal flooding because they only strike marine areas and do not spread far across the surface. Furthermore, the findings found that the main source of the destruction was due to the hydrodynamic force and/or impact force that the debris had created [1], [2]. Capable of understanding the loads caused by floods will thus help to improve the design and installation of flood-resistant buildings. The construction and building guidelines currently being pursued by [3] are recommending specific methods to characterize the debris effect load, but these are not well developed.

The structural susceptibility of buildings in flood flows is generally modeled Depends on the water depth and flow rate together. The Guidelines were extracted from historic flood data but their empirical investigation is severely minimal. There's a need to address for the significant number of complexity associated in such procedures motivates the recent positioning towards the more established and simple deterministic approaches to risk assessment. Past research has revealed by post-disaster surveys that vegetation helps to reduce the adverse consequences of natural disasters. Few prominent ones around the world are discussed briefly here. Both vegetation density and thickness on the upstream side raise the increase in the backwater. Depending on its configuration and thickness a forest can offer sufficient opposition to a flood force experimentally and numerically studied the influence of vegetation density and reported that both the water level and velocity behind the vegetation are greatly decreased by rising the aspect ratio of the vegetation [4]. The floating debris taken by a flood can intersect with buildings and then cause them additional damage. Vegetation is not only vital, but several factors are crucial for catastrophic variations in floods. Experimental analysis was conducted and it was found that even in sparse situations, two rows Vegetation system more driftwood than the single row Vegetation. As aspect ratio is enhanced, more driftwood is grown. Inland forest trees can handle the stress of floating debris and can also withstand the trapped debris as per velocity and Froude number of flow [5]. Tanaka and Ogino [6] studied in detail about the Impulse force on the locally constructed houses by the colliding of water-born floating debris. This paper studies the impact of waterborne debris on the local model house in the presence and absence of vegetation on the structural buildings

During floods, debris collide with houses that exist in the route way of flood water, generating an impact, hydrostatic and hydrodynamic loading on houses. Debris transported by floodwater strike residential or other structures in the floodplain. These impacts reduce the velocity of the debris and impart a force to the structure. The magnitude of the force can be large enough to cause substantial, or even catastrophic, damage to the structures. The aim of this research is to measure impact forces on model house due to floating debris based on mass and velocity of prototype woody debris by experimental setup as well as numerical analysis.

2 FORCES ON BUILDING DUE TO FLOOD BORN DEBRIS

Building structural fragility based on both the demand (loading) and structural sustainability (capability). This research is focused on the loading of the structure caused by the flood. During severe disasters, the development of floodplains of high flood-induced dangerous areas can be exposed to a range of forces, involving impact forces hydrostatic force and hydrodynamic force.

2.1 Impact force

FEMA P-55(2011) proposed an equation to investigate impact force which is

$$F_i = WVC_D C_{str} C_B \qquad (1)$$

In which F_i refers to the impact force, W stands for the debris weight, V is the debris velocity, $C_D C_{str}$ *and* C_B are the depth, building structure, and blockage coefficients, respectively. Based on the flow depth the depth and blocking coefficients range from 0-1. In the meanwhile, C_{str} is based on the form of structure, the direction, the natural phase, and the period of the impact. The coefficients provided in Eq.1 are derived from the findings of the laboratory and the conclusions about engineering.

The FEMA P-646 (2012) [7] provided the formula to calculate debris impact forces that differed from the previous version, and the following is:

$$F_i = 1.3\, u_{max}\sqrt{km_d(1+c)} \qquad (2)$$

For which, u_{max} refers to the maximum velocity of flow close to the structure. The velocity of the moving debris is believed to be equal to the velocity of flowing water. k,m_d, c refers to the combined rigidity of the impacted structures, the mass of the debris, and the hydrodynamic mass coefficient respectively. As per FEMA P-646 [7] for wooden debris, for debris that flows parallel to the flow direction, $c = 0$, for debris with a transverse orientation towards flow direction $c = 1$, Whereas for debris such as 20-ft and 40-ft cargo ships, $c = 3$ and $c = 2$ respectively.

2.2 Hydrostatic force

The horizontal hydrostatic force is extracted from the change in water level on wall upstream and downstream sides. It is given per unit length by:

$$F_{h,static} = \frac{1}{2}\rho g\,(h_{us}^2 - h_{ds}^2) \qquad (3)$$

Where ρ and g are the density of water and the gravitational acceleration respectively while as h_{us} and h_{ds} are referred to as depth of water upstream and downstream of the wall.

2.3 Hydrodynamic force

Hydrodynamic force is resulted from a composite of inertia and drag, while as it depends on both kinematics and dynamics of the flow and characteristics of structure respectively. The following concise expression is, in general, followed for the Hydrodynamic force per unit length is

$$F = C_d.\rho.g.h.u^2 \qquad (4)$$

Where C_d is the drag coefficient, h and u are the depth of water near wall and velocity component orthogonal to the object respectively.

3 EXPERIMENTAL PROCEDURE AND FLUME CHARACTERISTICS

In a glass-sided water flume (constant bed slope 1/500) that is 11 m long, 0.30 m wide, and 0.34 m high at the University of Engineering and Technology Taxila., laboratory tests were performed under various conditions. The schematic figure of the water channel is shown in Fig.1 (a). A small scale (1/45) of a wooden house was designed to test the relationship of the bore structure and the effect of debris on the structure. This building has a height of 0.15 m, a width of 0.10 m, and a length of 0.10 m and provided an equal building height of 675 cm, a length of 457 cm, and a real building width of 457 cm. As per the horizontal impact of debris, three equations (Eq.2, 3, and 4) were used to measure the reaction forces on the house model. A high-speed digital camera was used to monitor the behavior of the structure model and the velocity, direction, and effect of debris flow with the house model.

Table 1: Experimental Condition

Case No	Initial Froude Number (*Fr*)	Vegetation Density (*G/d*)	Vegetation Thickness (dn)	Vegetation Type	Building Distance (cm)
1	1.12	1.09	150	Transition	200

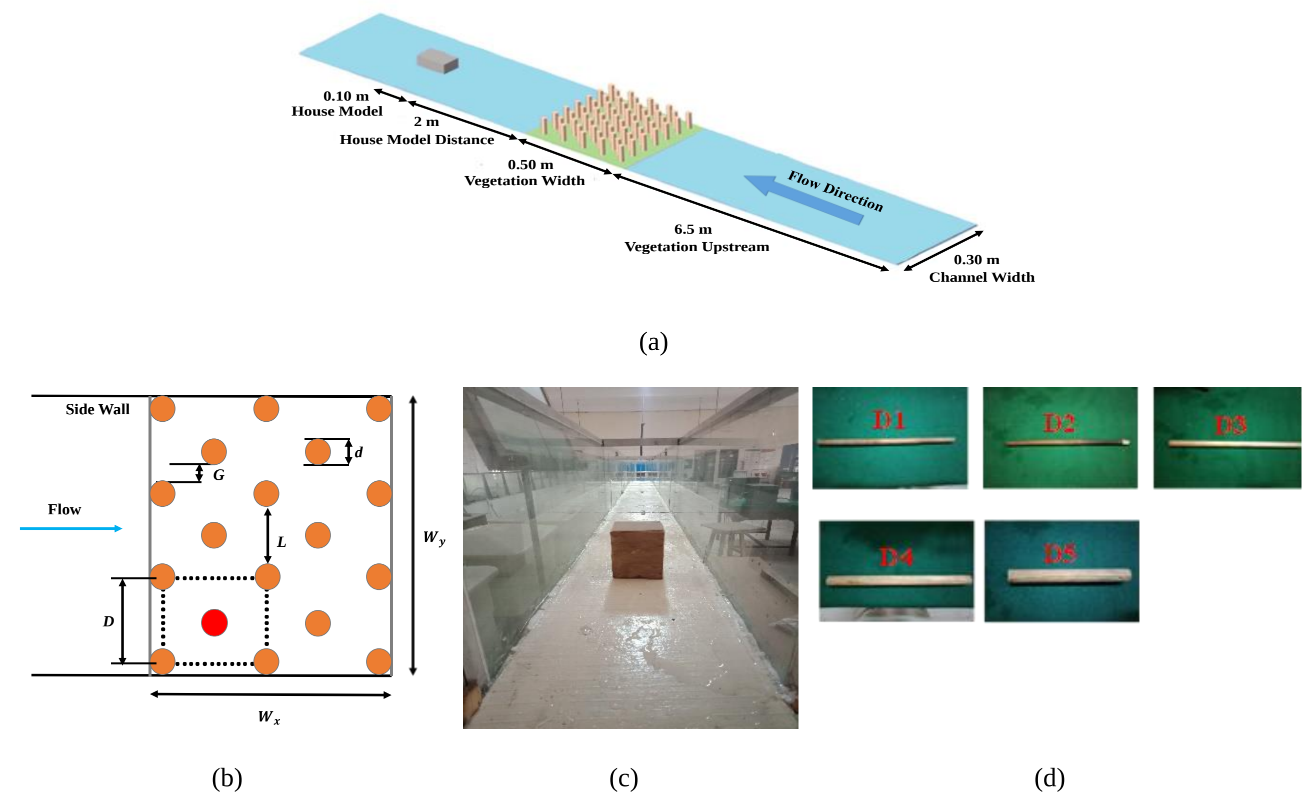


Figure 1: Experimental setup (a) Schematic diagram of the vegetated open channel (b) details of vegetation arrangement (c) house model and (d) types of debris

Five pieces of wooden planks in the staggered arrangement shown in Fig. 1(b) each with various sizes, diameter, and weights, was used to measure the effect caused by the wood debris. Moreover, the wooden house model in the open channel is shown in Fig.1 (c). The debris weight was then selected to fit target weights of 13.8 g, 15.8 g, 19.4 g, 45 g, and 33.9 g to reflect the debris scale of 1/45. The complete detail of debris used in the present experimental work is given in shown in Fig.1 (d) and table 2.

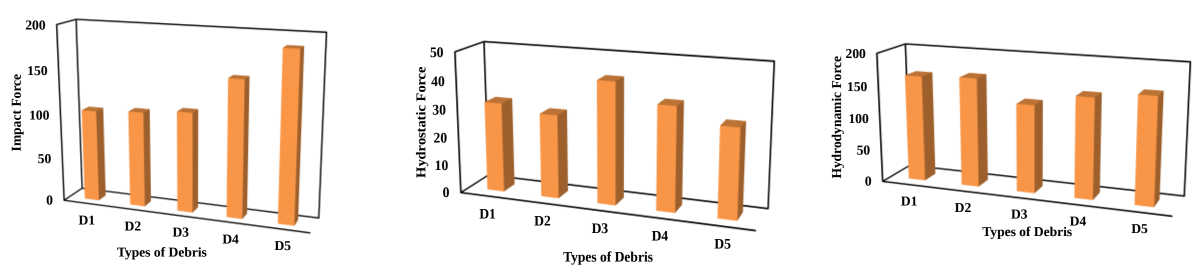
Table 2: Debris used in the present work are

Debris Type	Length (cm)	Diameter (cm)	Weight (g)
D1	24.5	0.75	13.8
D2	23	1	14
D3	26.5	1.25	19.4
D4	14	1.7	33.9
D5	24	1.7	45

4 RESULTS AND DISCUSSION

4.1 *Debris Impact, Hydrostatic, and Hydrodynamic Forces.*

Fig. 2 represent the experimentally derived values on the composition of the debris, and they were determined using the formulas given in the design guidelines. FEMA P-55[7] (Eq. 2, 3, and 4) to investigate the impact force (Fig.2a), Hydrostatic force (Fig.2b), and Hydrodynamic force (Fig.2c) of all debris given in table 2. The Forces displayed in Fig. 2 are based on the velocity of the debris that is measured experimentally. For wooden log debris, FEMA P-646 [7] suggested C=0 and k=2.4×10^6.



(a) (b) (c)

Figure 2: Comparison of waterborne debris (a) impact force (b) Hydrostatic force (c) Hydrodynamic force

Fig. 2 (a) revealed that the impact force was directly related to the mass of debris. The highest value of impact force was observed for D5 while as the minimum value for the D1 debris. Similarly, for the hydrostatic force which depends upon u/s and d/s water head, D3 showed the highest value for its larger length (26.5 cm) as compared to other debris (D1, D2, D4, and D5). D2 debris showed lower value because of shorter length (23 cm) and lower value of diameter (1 cm). The lower magnitude of hydrodynamic reflects the lower values of water accumulation at the upstream of the house model. For the dynamic force, the D2 type of debris showed the highest value compared to D3 which showed the lowest value because this force depends on the flow velocity. As the flow velocity and debris velocity were the same, so it was verified from the experiment that higher flow depth due to the larger value of length reflect the lower value of velocity shown in Fig. 2(c).

4.2 Water Surface Profiles (WSP)

Three different cases were considered to reflect the water surface profile that includes the without vegetation and house model, only vegetation and vegetation with house model profiles shown in Fig. 3. The experimental domain was taken at some distance from the channel inlet to prevent disturbance created at the channel inlet. The undulation in water depth was achieved at the upstream of only vegetation case and vegetation and house model case. It illustrated that the single hydraulic jump was created at the downstream of vegetation in only vegetation case and two hydraulic jumps were created at the downstream of vegetation and house model in vegetation and house model case.

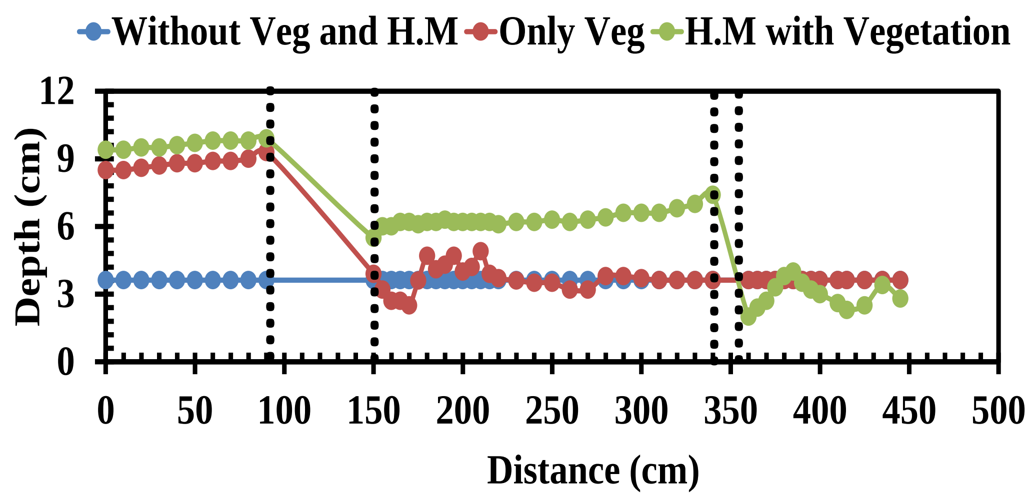


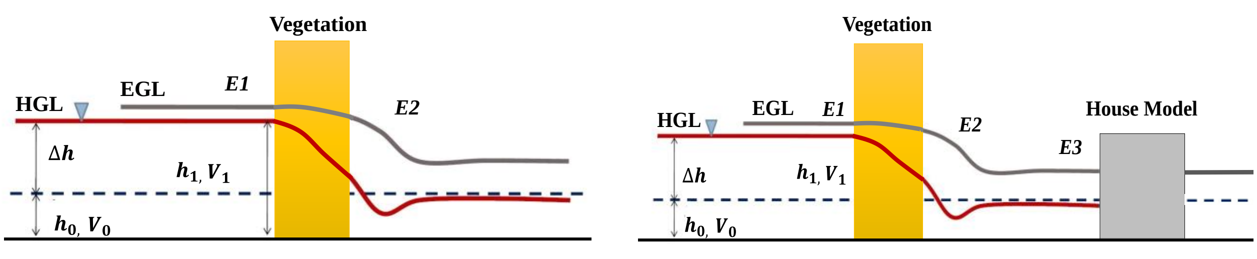
Figure 3: water depth measurement of the experimental domain

4.3 Energy Dissipation

It involved the specific energy E, flow velocity V, and water depth y can be written as Chow [8].

$$E = y + \frac{V^2}{g} \qquad (5)$$

In which y is water depth and where g is gravitational constant. This equation will be used to calculate energy dissipation, which is the difference between upstream and downstream energy. In the current study, we consider the dissipation of energy in terms of the total loss of energy ($\Delta E = E1\text{-}E2$) and relative total loss of energy (ΔE / E). Water depth in the presence of only vegetation can be observed in Fig. 4(a). Moreover, the energy dissipation was upto18 % at the downstream of the transition arrangement of vegetation.



(a) (b)

Figure 4: Flow behavior and difference of different parameters in the presence of (a) only vegetation and (b) vegetation with a house model.

Moreover in the presence of a house model with vegetation energy variation of energy in the form of dissipation was observed up to 19% shown in Fig. 4(b). It means that that vegetation played a vital role to dissipate the energy.

5 CONCLUSION

Evaluating the structures' stability in flood-prone areas is a crucial concern in evaluating flood-induced risks, particularly for its strong correlation of life loss during these tragic events. Keeping this in mind, a new series of studies has been carried out at UET Taxila to spread further light on flood-induced load dynamics and their impact on houses and to establish state-of-the-art measurements for the community. This research then compared experimental findings with the FEMA P-646 (2012) calculations which were suggested. It was noted during the analysis that the equation suggested by FEMA P-646 offered a better and more precise calculation of the forces of impact, hydrodynamic and hydrostatic. Initial findings indicated that impulsive loading may be considerably higher than those expected by current forecasting methods and should be seen as potentially important when evaluating the vulnerability of existing structures and constructing flood-proof buildings

ACKNOWLEDGMENT

The authors would like to thank the University of Engineering and Technology Taxila for providing the equipped Hydraulics Lab. The anonymous reviews are gratefully thanked for their close analysis and positive feedback.

REFERENCES

[1] D. Palermo, I. Nistor, T. Al-Faesly, and A. Cornett, "Impact of tsunami forces on structures the university of Ottawa experience," Sci. Tsunami Hazards, vol. 32, no. 2, pp. 58–76, 2013.
[2] M. Saatcioglu, A. Ghobarah, and I. Nistor, "Performance of structures in Indonesia during the December 2004 Great Sumatra earthquake and Indian Ocean tsunami," *Earthq. Spectra*, vol. 22, no. SUPPL. 3, pp. 295–319, 2006.
[3] "Development of a Probability Based Load Criterion for American National ... - Bruce Ellingwood - Google Books." [Online]. Available: https://books.google.com.pk/books?hl=en&lr=&id=KvchPLsPwZ8C&oi=fnd&pg=PA1&dq=Minimum+design+load+for+building+and+other+structure&ots=m8RtbdJALW&sig=1KkY9qv9kALiaNtCNwdzwnVtvF0&redir_esc=y#v=onepage&q=Minimum design load for building and other structure&f=false. [Accessed: 17-Jul-2020].
[4] G. Ahmed and N. Tanaka, "Undular hydraulic jump formation and energy loss in a fl ow through emergent vegetation of varying thickness and density," *Ocean Eng.*, vol. 141, no. June, pp. 308–325, 2017.
[5] G. A. Pasha and N. Tanaka, "Effectiveness of Finite Length Inland Forest in Trapping Tsunami-Borne Wood Debris," *J. Earthq. Tsunami*, vol. 10, no. 4, pp. 1–26, 2016.
[6] N. Tanaka and K. Ogino, "Comparison of reduction of tsunami fluid force and additional force due to impact and accumulation after collision of tsunami-produced driftwood from a coastal forest with houses during the Great East Japan tsunami," *Landsc. Ecol. Eng.*, vol. 13, no. 2, pp. 287–304, 2017.
[7] D. Bass and V. Koumoudis, "FEMA's Coastal Construction Manual Update—Flood-Resistant Design," in *Advances in Hurricane Engineering*, 2012, pp. 128–135.
[8] V. C.-Mcg. Hiu and undefined 1959, "T. 1959 Open-Channel Hydraulics."

DRIVER AND PEDESTRIANS INTERACTIONS CHARACTERIZATION

[a] Gauhar Amin, [b] Akhlaq Aman
a: National Institute of Urban Infrastructure Planning, University of Engineering and Technology, Peshawar, Pakistan, 25000,
b: University of Engineering and Technology, Taxila, Pakistan Taxila 47050, Pakistan;
a: gauharamin453@gmail.com
b: akhlaqaman13@gmail.com

Abstract-Traffic accidents comprising pedestrian have been a huge problem in third world countries. These accidents occur due to robust and greater number of urban infrastructural developments, increase in the number of vehicles and lack of traffic rules followed by the drivers and pedestrians. The basic road design in the developing countries does not provide pedestrian safety. A case study has been conducted at Inter Junction Principal (IJP) Road in Rawalpindi to find out the effect of pedestrians on traffic flow. Similarly, a linear relation has been found between the flow and density while an inverse relation of the travel time with flow and density.

Keywords- Pedestrians, Speed, Density, Travel Time, Flow, Vehicles

1 INTRODUCTION

Developing countries around the world have problems of transportation in context of traffic jams and accidents. These problems are mainly attributed to the increase number of road user. The basic design of the road does not provide frequent safety provision for the pedestrian in Pakistan [1, 2]. It provides limited space for pedestrians for road crossing which causes accidents. Drivers has a small reaction time to avoid accidents. Most of the fatalities in developing countries are due to lack of pedestrians crossing facilities [1]. As per the World Bank Estimation in 1996, total deaths on road were 500,000. 350,000% of these accidents were occurred in the developing countries [1]. In 1994 at Karachi, Pakistan 462 of road accidents occurred due to pedestrians. In the US only 14.5% of pedestrians were involved in road accidents [3]. Globally, more than 270,000 pedestrians lose their lives in the road accidents [4]. Approximately 1.35 million of peoples loss their lives on the roads. Most of these accidents occur in urban areas [3]. 80% pedestrian accidents occur by striking of cars, Lories, and buses while only 20% of accidents occur by striking each other at designated crossing. In 2013, 12,385 deaths of pedestrians were occurred in India [1]. There are various factors which governs a pedestrian decision to cross a road. Children misjudge safer gap than adults during road crossing [5]. Two studies of pedestrians crossing in Israel showed that men are more likely to move along the crossing than women when the walker passage light was red. The pedestrian involved in eating or hearing through headphone were less aware [6]. Environmental factor also plays an important part in the pedestrian decision to cross the road. In rain and windy weather, a pedestrian hesitates while crossing a road [7]. Pedestrian wait when a large number of vehicles are moving towards an intersection or when a vehicle has high speed [8]. The conduct of the pedestrian crossing is classified into different classes i.e. two gaps, risk taking, two phases and walking & look. Single level and rolling at different facilities. Studies of pedestrian gap acceptance and vital gap have shown that walking speed and road width can determine that a pedestrian embrace or refuses gaps and there is a 2s difference between lag and gap [9]. Standards were established to observe the length of the traffic spaces accepted by walkers. Certain endeavors have been done to investigate the road traversing attitude of walkers in blended movement condition. Road traversing attitude of walker with regard to the demographic features have been found in different studies. Various research has too dug into the significance of pedestrians velocities at various location and they delineated that men walk remarkably quicker than women while crossing the roads [10]. Researches on crossing mood were also done by different researchers and they concluded by categorizing the pedestrians crossing behavior into three classes i.e. single stage, two stage, and rolling. It was found that with one way traversing number of pedestrians were larger for two stage gaps, on the other hand single stage crossing was frequent on two way roads [11]. It is clear that interactions exist between pedestrians and vehicles on roads. The basic design of a road in the third world countries does not provides frequent safety provision for the pedestrian. It provides limited space for pedestrian in a lane, and crossing which causes complication between pedestrian and vehicle at crossings.

Objectives of the Study

The study is focused on de pedestrians and vehicles interactions to analyze the basic flow parameters like speed and density in the presence and absence of the pedestrians.

2 SCOPE/SIGNIFICANCE OF THE STUDY

Huge traffic jam in modern time is mitigated by traffic modelling. It is actually a virtual tool to solve the traffic congestion issues. Congestion causes greater traveling cost and social stresses. To cope with these problems, a traffic data analysis is required to solve congestion problems due to pedestrians such as

- Congestion minimization
- Enhancing speed
- Save the cost on huge infrastructure.

3 RESEARCH METHODOLOGY

For data collection Inter Junction Principal (IJP) Road Faizabad, Rawalpindi is chosen as large number of pedestrians crosses the road width. Secondly, the metro station Faizabad overpass over IJP road is suitable for a top view video recording. Videos were recorded at 8 AM, 2 PM, and 4 PM. Camlytics software was used to detect vehicles and pedestrians crossing at the selected section. Travel time was calculated in this section.

3.1 *Traffic Conditions on Monday, Tuesday and Wednesday:*

Table 34: Effect of Pedestrians on Travel Time, Speed, Density and Flow

S. No	No of Pedestrians			Travel Time (s)			Speed (km/hr.)			Density (veh / km)			Flow (veh / hr)		
	Mon	Tues	Wed	Mon	Tues	Wed	Mon	Tues	Wed	Mon	Tues	Wed	Mon	Tues	Wed
1	0	0	0	1.64	1.76	1.37	71.53	61.37	78.64	80	80	80	8583	7364	6291
2	1	1	1	1.81	2.09	1.87	60.57	57.23	60.12	80	80	80	4845	6867	4809
3	2	2	2	3.27	2.63	2.13	52.5	48.51	58.96	60	60	60	4200	3880	3537
4	3	3	3	3.69	3.02	4.56	29.21	35.73	38.41	60	60	60	1168	1429	2304
5	4	4	4	8.14	3.55	2.92	13.26	32.19	37.34	40	40	40	530	1287	1493
6	5	5	5	7.01	4.07	3.55	15.40	23.44	36.60	40	40	40	616	937	1464

Table 1 depicts that on Monday in the absence of pedestrian a maximum average speed of 71.53 Km / h is recoded but as a pedestrian appears in the road section, the speed decreases to 60.57 Km / h. With the increase in number of pedestrians, the speed reduces more drastically. Presence of five pedestrians in the section reduce the speed to 15.4 Km / h which is 21.5% decrease in the speed when there were no pedestrians in the section. While the presence of pedestrians also effects the density and reduces it to 33% when there were no pedestrians in the section. Similarly flow value also decrease with the increase in number of pedestrians in the section and reduce to 10%.

As it is cleared from Table 1 also that a maximum speed of 61.37 Km / h is recorded on Tuesday, when there was no pedestrian on the road for which the density value is 120 so it gives us a maximum flow of 7364. But as the pedestrians appear in the section, the speed start decreasing according to the numbers of pedestrians and the density and flow values also goes on decreasing. Presence of five pedestrians in the section reduce the speed to 23.44 Km / h which is 38% decrease in the speed as compared to the speed in the absence of pedestrians. While the presence of pedestrians also effects the density and reduce it to 33%. Furthermore, flow value also decreases with the increase in number of pedestrians in the section and reduces to 12.7%.

As shown in Table 1 for day Wednesday, maximum speed 78.64 Km / h is observed in the absences of pedestrians for which the density value is 80 and the maximum flow value is 6291, while the minimum speed is 36.6 Km/h for which the density is 40 and minimum flow recoded is 1464 veh /h. Presence of five pedestrians in the section reduce the speed to 36.66 Km / h which is 46% decrease in the speed as compared to speed, when there was no pedestrians in the section. While the presence of pedestrians also effects the density and reduce it to 50%. Moreover, flow value also decreases with the increase in number of pedestrians in the section and reduces it to 23%.

4 RESULTS

For data extraction and analysis, a 0.025 km section was considered. For Travel time extraction form the traffic flow Camlytics software was used. Camlytics software actually detects the entrance and exit of vehicles in a section. All data were run through Camlytics for data extraction. After getting the Travel time and other variables like speed, density and flow were easily determined using proper formulas in the excel sheet.

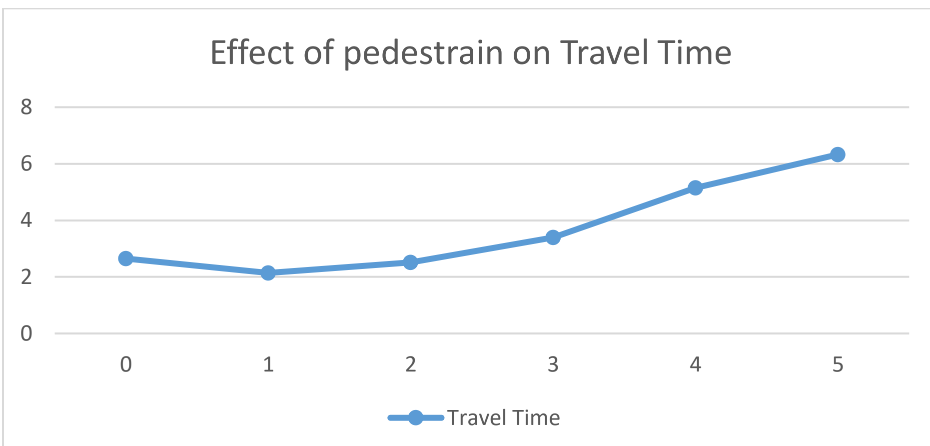


Figure 8: Effect of Pedestrians on Travel Time

Figure 1 shows the effect of pedestrians on the travel time of the vehicles. At the very start when there is no pedestrian in the section the travel time is 2.65 s but as the numbers of pedestrians increases in the section in the section, the travel time also increases and reach to a value of 6.33 s that is 41 % increase in the travel time.

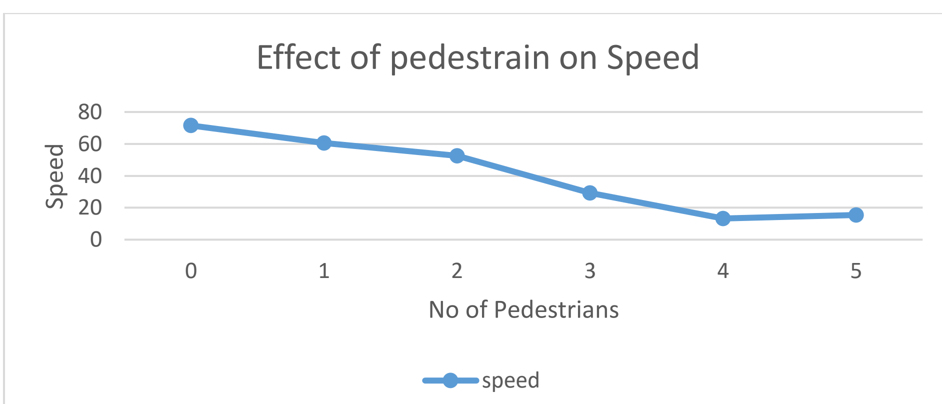


Figure 2: Effect of Pedestrians on Speed

The effect of pedestrians on the traffic speed is shown in Figure 2. At the very start in the absence of pedestrian the speed is maximum 71.53 Km / hr. but as the number of pedestrian crossing from one side to other side of the road, they reduce the speed accordingly. The presence of five pedestrians in the section decrease the speed up to 15.4 Km / hr. which is 21.5% decrease in the speed in comparison to the speed in the absence of any pedestrian.

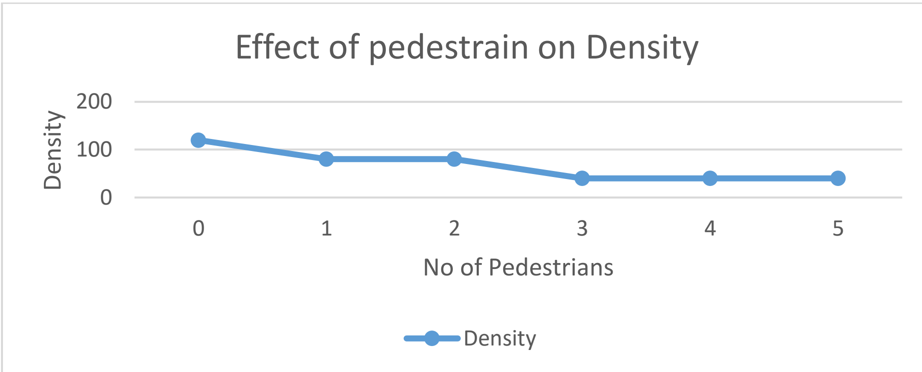


Figure 3: Effect of Pedestrians on Density

The effect of pedestrians on the traffic density is shown in Figure 3. In the very start when there was no pedestrian in the section the density is 120 veh / 0.025 Km but as the number of pedestrians increases in the section, the density value decreases and goes down to a value of 40 veh / 0.025 Km when there are five pedestrians in the section. These fives pedestrians have decreased the density value by 33%.

5 PRACTICAL APPLICATIONS THE WORK

- Effect of pedestrians on the density flow and speed can be determined.
- Strict law abidance in those area where pedestrians crosses road without using zebra crossing.
- An overpass also minimizes the pedestrians directly crossing over the road.

6 CONCLUSIONS

Sequel to compiled results and discussions, following conclusions are made:-

1. Presence of pedestrians in a section effect the traffic flow directly.
2. Presence of pedestrians in a section enhance the Travel time as in our case the travel time was increase up to 41 %.
3. Presence of the pedestrians also effect the speed. As from figure 2 it is evident that the speed was reduced by 21.5 % when five pedestrians were present in the section.
4. Presence of the pedestrians also effect the density of the traffic flow. As from the figure 3 it is clear that the density has been decreased by 33 %.

7 RECOMMENDATIONS AND FUTURE WORK

1. A model can be prepared by using driver's pedestrian's interaction analysis.
2. An alternate way for pedestrians can be determined so that less interaction is observed between drivers and pedestrians.
3. A new model can be postulated based on geometric design.

4. The proposed data can be practically validated.
5. The proposed data analysis can be adopted by traffic representation for ITS

ACKNOWLEDGMENT

I am cordially thankful to Engr. Waheed Imran (Traffic Flow Modeler) for his valuable suggestions and help throughout this study. I am also grateful to Engr. Muhammad Arshad, Engr. Ijaz Ul Haq and Engr. Akhlaq Aman.

REFERENCES

[1] D. Drakakis-Smith and E. Young, "Third World in the First: Development and Indigenous Peoples", The Geographical Journal, vol. 162, no. 2, p. 227, 1996. Available: 10.2307/3059894.

[2] M. Khanal and P. Sarkar, "Road Safety in Developing Countries", Journal of Civil & Environmental Engineering, vol. 2, 2014. Available: 10.4172/2165-784x.s2-001.

[3] F. Khan, M. Jawaid, H. Chotani and S. Luby, "Pedestrian environment and behavior in Karachi, Pakistan", Accident Analysis & Prevention, vol. 31, no. 4, pp. 335-339, 1999. Available: 10.1016/s0001-4575(98)00075-x.

[4] W. Odero, P. Garner and A. Zwi, "Road traffic injuries in developing countries: a comprehensive review of epidemiological studies", Tropical Medicine & International Health, vol. 2, no. 5, pp. 445-460, 1997. Available: 10.1111/j.1365-3156.1997.tb00167.x.

[5] F. Khan, M. Jawaid, H. Chotani and S. Luby, "Pedestrian environment and behavior in Karachi, Pakistan", Accident Analysis & Prevention, vol. 31, no. 4, pp. 335-339, 1999. Available: 10.1016/s0001-4575(98)00075-x.

[6] F. Bella and M. Silvestri, "Effects of safety measures on driver's speed behavior at pedestrian crossings", Accident Analysis & Prevention, vol. 83, pp. 111-124, 2015. Available: 10.1016/j.aap.2015.07.016.

[8] J. Faria, S. Krause and J. Krause, "Collective behavior in road crossing pedestrians: the role of social information", Behavioral Ecology, vol. 21, no. 6, pp. 1236-1242, 2010. Available: 10.1093/beheco/arq141.

[9] G. Ren, Z. Zhou, W. Wang, Y. Zhang and W. Wang, "Crossing Behaviors of Pedestrians at Signalized Intersections: Observational Study and Survey in China", Transportation Research Record: Journal of the Transportation Research Board, vol. 2264, no. 1, pp. 65-73, 2011. Available: 10.3141/2264-08.

[10] S. Chandra, R. Rastogi and V. Das, "Descriptive and parametric analysis of pedestrian gap acceptance in mixed traffic conditions", KSCE Journal of Civil Engineering, vol. 18, no. 1, pp. 284-293, 2013. Available: 10.1007/s12205-014-0363-z.

[11] M. Ishaque and R. Noland, "Behavioural Issues in Pedestrian Speed Choice and Street Crossing Behaviour: A Review", Transport Reviews, vol. 28, no. 1, pp. 61-85, 2008. Available: 10.1080/01441640701365239.

DEVELOPMENT OF A SHEAR THICKENING FLUID AND ITS USE AS A MODIFIER IN ASPHALT BINDER

[a]Tanveer Hassan, [b]Naveed Ahmad, [c]Syed Bilal Ahmed Zaidi
Department of Civil Engineering, University of Engineering and Technology Taxila, Taxila 47050, Pakistan;
a: tanveerhassan453@gmail.com
b: n.ahmad@uettaxila.edu.pk
c:bilal.zaidi@uettaxila.edu.pk

Abstract- This study presents development of a Non-Newtonian fluid, also referred to as a Dilatant or Shear Thickening Fluid (STF), and its use as an additive/modifier for improvement of different visco-elastic properties of bitumen. Dosage optimization of STF was done with the help of Superpave performance grading (PG) technique and other conventional asphalt binder tests. Storage stability test was carried out to ensure the stability of the new STF modified bitumen samples. Binder samples were prepared using different dosages of STF and then different conventional and rheological tests were used to study the effect of STF on the properties of modified binders. From the results of investigations, an optimal dose of 4% STF by weight of the binder is selected for upgrading the binder properties. The addition of 4% STF helped to improve the high-temperature visco-elestic properties of the asphalt binder which is a major requirement of the local pavement industry in Pakistan. STF improved the high-temperature range of the binder under study from Superpave PG 52 to PG 64.

Keywords-Shear Thickening Fluid, Performance Grading (PG), Complex Shear Modulus, Modified Bitumen

1 INTRODUCTION

Bitumen is a very complex material, exhibits both viscous and elastic response at the same time, and these responses are highly dependent on both the traffic loading and the temperature[1], [2]. Experts, engineers and researchers have used a variety of additives and modifiers to upgrade the performance of asphalt materials in different loading and environmental circumstances. The modifiers include styrene butadiene styrene (SBS) [3], [4], crumb rubber [5], [6], styrene-butadiene-rubber (SBR) [7], [8], waste fibres [9], ethylene glycidyl acrylate (EGA) terpolymer[1] and waste tire rubber[10].

During the past decade nano-technology has grabbed the attention of the material industry; it has been extensively used in various fields. Asphalt binder has been modified with different nano-materials such as nano-Silica, Nano-clay, Single-wall nano-tube (SWNT), and with nano-fibers of carbon. The developed binder samples are subjected to different laboratory investigations including rheology (DSR), fatigue and visco-elastic characteristics, and their mixing procedures are also investigated. Results from these investigations showed that nano-materials helped improve different parameters such as rut resistance, complex shear modulus (G^*), viscoelastic-plastic behaviour of the binder, and fatigue life [11]–[13]. Upper temperature performance of the binder can also be improved by using nano-clay as an additive [14]. Addition of carbon microfibers in bitumen also helped enhancing the resistance against moisture susceptibility [15].

As discussed above nano-technology is emerging very rapidly and showing its usefulness in many fields. Shear thickening Fluid (STF) is one of the best emerging applications of nano-technology which is also called Dilatant. A Dilatant is composed of nano-particles that are suspended in a solvent (Carrier Fluid). Dilatant (STF) is a non-Newtonian fluid [16] whose viscosity dramatically increases with the increase in shear rate above a certain threshold value. When the energy from the impact is dissipated the material reverts back to a liquid [17]. Particle size, concentration, distribution, shape, particles dispersions and particle to particle interaction are all the factors that affects the commencement of shear thickening effects [18]. Numerous studies have been made on the Dilatant and generated vast quantity of patent filings due to its extra ordinary potential since their discovery. The most common uses and suitability of Dilatant that are discovered till now includes its use in personal protection material, sports and in body armour [19]. Although several studies have been made to investigate uses of the dilatant but still a lot of efforts are required to further explore potential uses of this material.

As discussed, earlier STF is an emerging technology and showing it's applications in many fields but this material was never used before for asphalt modification so, through this study, an attempt has been made to check the effects of STF on high temperature performance of the bitumen. The STF used in this study was prepared from Nano-Silica dispersed in ethylene Glycol because silica nanoparticles are one of the very best material for a shear thickening fluid [18]. The STF was added to virgin bitumen because it could improve different rheological and conventional properties of the asphalt binder especially for high temperature applications. High temperature performance of asphalt pavements is a major concern of local pavement industry in Pakistan, as flexible pavements fail prematurely when exposed to high summer temperatures and excessive loading. Local pavements fail due to excessive permanent deformation of the asphalt mix far before reaching the end of its fatigue life. To address these problems several modifiers have been used to improve binder performance. The most commonly polymers (SBS, SBR) and acids, especially polyphosphoric acid. The PMBs have certainly improved the performance of asphalt binder but, the issue with PMBs is that of storage stability and are unstable to be stored for a longer time. On the other hand, PPA modified asphalt binders have been found adequate in their performance but still lack in some properties such as difficulty to handle during mixing, higher temperature requirement for mixing, due to higher viscosity and instability at elevated temperatures. "So by using STF as modifier we have made an attempt to develop such a modifier which enhance the viscoelastic performance of the binder, which is environmental friendly as it will require less heat and time for mixing, easy in handling and storage stable also". The STF was added in the base binder in different concentrations by weight of the base binder and then for the rheological and performance evaluation of the modified samples different asphalt binder tests were performed such as the shear thickening test of modifier, bitumen conventional tests, and dynamic shear rheometer (DSR) investigations. Storage stability of the modified samples was also checked. Details of the experiments and discussions of outcomes from the results obtained are presented in the subsequent sections of the manuscript.

2 EXPERIMENTAL WORK

2.1 Materials

Control asphalt binder of pen grade 80/100 was obtained from Attock Refinery Limited (ARL), Pakistan. Nano- Silica was imported from Dalian Fuchang Chemicals China and Ethylene Glycol was imported from Honeywell Germany. Tables1, 2 and 3 presents the properties of these materials respectively.

Table 35: Properties of Control Binder

Test	**Value**	***Standard***
Softening Point (◦C)	*48*	ASTM D36
Penetration Value (0.1 mm)	*95*	ASTM D5
Ductility mm (25 ◦C)	*108*	ASTM D113

Table 36: Properties of Nano-silica

IngredientName	**Purity**	**Size**	**Specific area**	**Melting point**
Silicon Dioxide	*>99%*	*12 nm*	*200* m^2/g	*>300 ºC*

Table 37 Properties of Ethylene Glycol

Material Name	Purity	Boiling Point	Freezing Point	Density
Ethylene Glycol	*>99%*	*197 ºC*	*-12 ºC*	*1.11 g/cm^3*

2.2 Sample Preparation

The sample preparation is divided into two parts. In the first part a Shear Thickening Fluid (STF) or Dilatant is prepared while in the second step the STF is mixed with base binder to produce STF Modified Bitumen.

2.3 Preparation of Shear Thickening Fluid (STF)

STF is composed of two components the particles and a carrier fluid to fabricate them. STF prepared in this study was a high concentrated mixture of 40% nanoparticles and 60% Ethylene Glycol as carrier. As it was a high concentrated mix so, to get a homogenous mixture particles were added to the solvent in small increments and the blender was used to mechanically stir the mixture for 25 minutes after every incremental addition [19] and this process was continued until the exact ratio of 40:60 by weight was achieved. In order to get a homogenous result the mixture was stirred for 2 hours after the addition of the complete amount of the nanoparticles. To eliminate bubbles from the mixture the prepared STF was kept in open air for 24 hours. Mixing was done using high shear mixer at 3000 rpm.

2.4 Preparation of STF Modified bitumen

According to literature, different additives are mixed in the base binder with the help of high shear mixer, and the selected temperature range is 130 ºC to 165ºC, while the proposed duration of mixing range from 30 minutes to 60 minutes [21]. The prepared STF in this study was added to the base binder in three proportions (2%, 4% and 6%). Proportioning was made by weight of the binder. To get a uniform concentration the STF was introduced to the bitumen and was continuously mixed for 45 minutes at 130ºC using a high shear mixer at 3000 rpm. This procedure was carried out for each of the modified sample.

2.5 Shear thickening test of Dilatant (STF)

Steady state test was used to check the thickening behaviour of the modifier. In the steady state test the sample (40% of nano-silica in 60% ethylene glycol; by weight) were rotated in DSR by providing varying shear rate as input from 0.1 to 1000. Figure 9 represents viscosity as a function of shear rate for the prepared STF.

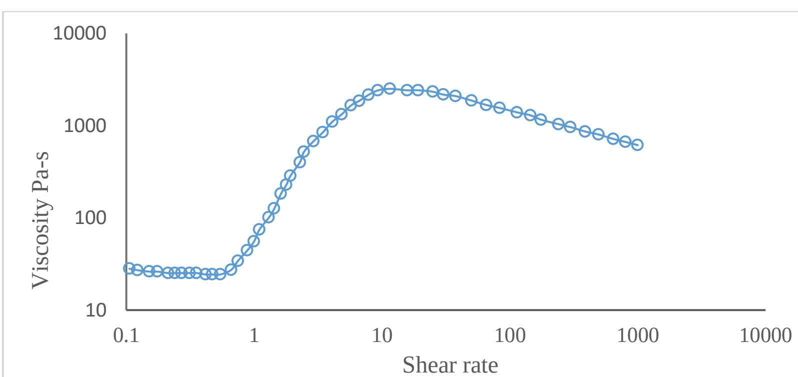


Figure 9: Viscosity as a function of shear rate for STF

From Figure 9it can be concluded that 40% concentrated STF has a clear shear thickening (non-newtonian) effect such that at low shear rate the viscosity gradually decreased and then the viscosity began to increase dramatically when the shear rate was above a critical value until it reached the peak viscosity value. After the shear thickening region, the viscosity decreased again[19].

2.6 Stability investigation of STF Modified Bitumen

To check the stability of modified bitumen the following test was conducted.

2.7 Storage Stability

Results of storage stability test verified the consistent diffusion of STF in the binder. Table 38 shows the results of the test. Stability was evaluated from the difference in top and bottom softening points, and the stability is considered as acceptable because the softening difference from top to bottom is less than 2.2oC.

Table 38: Storage Stability of Base and STF Modified Asphalt Binders

Sample ID	Softening Point		
	Top	Bottom	Top – Bottom
Base Binder	48.2	48.5	0.3
2% STF Modified	50.4	50.9	0.5
4% STF Modified	54.3	55.2	0.9
6% STF Modified	57.6	58.8	1.2

2.8 Conventional Binder Tests

The conventional physical properties tests on the modified and base binder Such as penetration, softening point and ductility were performed according to ASTM D5, ASTM D36 and ASTM D113 respectively. These tests were executed to examine the changes after the addition of STF in the binder.

2.9 Performance Grade (PG)

The PG grade of bitumen describes the low and high temperature at which the binder shows suitable behaviour and perform satisfactorily. As in this study we are mostly concerned with high temperature so, MCR101 Dynamic shear Rheometer (DSR) with parallel-plane geometry, 25mm dia and 1 mm gap was used to determine the required High PG of the base and modified binder. This test was performed according to AASHTO T315.

2.10 Rheological properties

For the rheological characterization DSR model MCR 101 by Anton paar with plane-parallel geometry, 25mm dia and 1 mm gap was used to perform the corresponding Frequency Sweep test. This test was performed to estimate the shear deformation performance and temperature sensitivity of the binder. Test was performed according to superpave criteria i-e with constant strain of 10% and ranged frequency from .1 to 10 HZ, furthermore these tests were performed on different temperatures from 10ºC to 82ºC with 12 ºC difference.

3 RESULTS AND DISCUSSIONS

3.1 Conventional binder Properties tests

Enlists the effect of STF on the softening, Ductility and penetration values of improved/modified and Base binder. The results show that by adding STF into the base binder there is an increase in the softening point and decrease in ductility and penetration values was recorded. By the addition of 2%, 4% and 6% STF to the base binder 7%, 18% and 22% reduction in penetration and 7%, 15% and 19% increase in softening point was recorded respectively. Softening point can be used as indicator to illustrate the stiffness of binder. From the observed results it can be concluded by the fusion of STF in Bitumen stiffness has been increased and the high temperature susceptibility has been reduced [22], [23].

Table 39 Results of conventional tests

Blends description	Penetration (1/10 of mm)	Softening(°C)	Ductility (cm)
Standard	**ASTM D5**	**ASTM D36**	**ASTM D113**
Base binder	96	48	112
2% STF	89	51	107
4% STF	79	55	99
6% STF	75	57	93

3.2 *Performance grade*

Results of PG test are presented in Figure 10which clearly demonstrates a substantial improvement in PG of binder when it was treated with different dosage of STF. With the increase in PG we can say that resistance to permanent deformation also increases in other words with the increase in PG of the binder resistance to rutting also improves. Hence we can say that by the addition of STF to the binder resistance to permanent deformation also increases, which is a main cause of road failure in Pakistan. From the results in the Figure 10 it can be seen that bitumen having PG 52 was valued to binder of PG 64 by the addition of both the dosage 4% and 6% STF, but 4% STF as modifier was selected as optimal dosage on the basis of PG test. We can conclude that Dilitant (STF) has the affinity to improve high temperature performance of the binder without compromising the lower temperature performance.

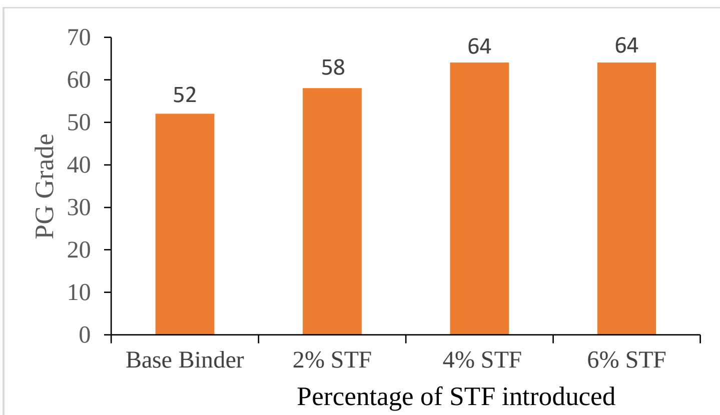


Figure 10 Effect of STF dosage on performance grading

3.3 *Rheological properties*

Figure 11represents the interdependency of reduced frequency and G*that is the complex shear modulus of the binder. From the investigations it was concluded that by the addition of 4% STF there is a 45% increase in the G*at frequency of 10 HZ, which means that the modifier is resulting in the stiffness of the binder. Lower left portion of the Figure 11 represents high temperature and low frequency zone, a significant increase can be clearly seen in that area which means that STF modified binder is more appropriate for high-temperature areas. Meanwhile it was also noted that upper right portion of the Figure 11 remained almost unchanged which represents low temperature and high frequency, so we can say that we have improved the high temperature properties without compromising low temperature performance.

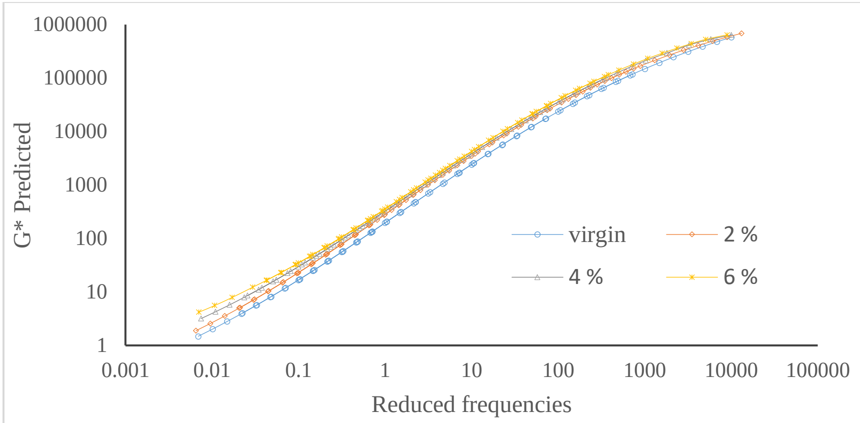


Figure 11 Relation between G and reduced frequency.*

4 PRACTICAL APPLICATIONS THE WORK

In the regions where summer season prevails and during the summers temperature reaches to very extreme which increases the surface temperature of the pavement due to which pre mature failure of the pavement may occur in the following two way:

1. It may lead to bleeding of the binder which effects the skid resistance of the pavement badly and
2. It may lead to heavy rut potential due to high surface temperature which is favoured by heavy axle loading

So by using STF as modifier the above mentioned failure mechanism can be highly reduced which will help the local pavement industry to maintain good and durable road network.

5 CONCLUSIONS

The following conclusions are made based on the test results performed on STF-modified binder

1. A good STF can be obtained by mixing of nano-silica and ethylene glycol in the proportion of 40:60 by weight
2. From Storage stability test we can say that STF was properly dispersed in binder and has produced a stable modified binder
3. The optimum dosage of 4% STF was selected, with the addition of this 4% STF the base binder of PG 52 was improved and modified to PG 64
4. With the addition of 4% STF the Penetration value has decreased by 18% and increased the softening point by 15% as as the ductility was reduced by 12%.
5. The complex shear modulus (G^*) of the binder enhanced meaningfully which means the elastic behaviour and stiffness of binder has been improved with the intrusion of STF in the binder
6. STF promoted high temperature performance without degrading the low temperature response

REFERENCES

[1] Y. Yildirim, "Polymer modified asphalt binders," *Constr. Build. Mater.*, 2007, doi: 10.1016/j.conbuildmat.2005.07.007.

[2] S. J. Peters, T. S. Rushing, E. N. Landis, and T. K. Cummins, "Nanocellulose and microcellulose fibers for concrete," *Transp. Res. Rec.*, 2010, doi: 10.3141/2142-04.

[3] M. S. Cortizo, D. O. Larsen, H. Bianchetto, and J. L. Alessandrini, "Effect of the thermal degradation of SBS copolymers during the ageing of modified asphalts," *Polym. Degrad. Stab.*, 2004, doi: 10.1016/j.polymdegradstab.2004.05.006.

[4] A. I. Al-Hadidy and T. Yi-qiu, "Effect of styrene-butadiene-styrene on the properties of asphalt and stone-matrix-asphalt mixture," *J. Mater. Civ. Eng.*, 2011, doi: 10.1061/(ASCE)MT.1943-5533.0000185.

[5] J. Shen, S. Amirkhanian, F. Xiao, and B. Tang, "Influence of surface area and size of crumb rubber on high temperature properties of crumb rubber modified binders," *Constr. Build. Mater.*, 2009, doi: 10.1016/j.conbuildmat.2007.12.005.

[6] F. Xiao, S. N. Amirkhanian, J. Shen, and B. Putman, "Influences of crumb rubber size and type on reclaimed asphalt pavement (RAP) mixtures," *Constr. Build. Mater.*, 2009, doi: 10.1016/j.conbuildmat.2008.05.002.

[7] H. Zhang, Y. Wang, Y. Wu, L. Zhang, and J. Yang, "Study on flammability of montmorillonite/Styrene-Butadiene Rubber (SBR) nanocomposites," *J. Appl. Polym. Sci.*, 2005, doi: 10.1002/app.21797.

[8] B. Zhang, M. Xi, D. Zhang, H. Zhang, and B. Zhang, "The effect of styrene-butadiene-rubber/montmorillonite modification on the characteristics and properties of asphalt," *Constr. Build. Mater.*, 2009, doi: 10.1016/j.conbuildmat.2009.06.011.

[9] B. J. Putman and S. N. Amirkhanian, "Utilization of waste fibers in stone matrix asphalt mixtures," in *Resources, Conservation and Recycling*, 2004, doi: 10.1016/j.resconrec.2004.04.005.

[10] W. Cao, "Study on properties of recycled tire rubber modified asphalt mixtures using dry process," *Constr. Build. Mater.*, 2007, doi: 10.1016/j.conbuildmat.2006.02.004.

[11] M. Khattak, K. A, and H. Rizvi, *Mechanistic Characteristics of Asphalt Binder and Asphalt Matrix Modified with Nano-fibers.* 2011.

[12] M. J. Khattak, A. Khattab, H. R. Rizvi, and P. Zhang, "The impact of carbon nano-fiber modification on asphalt binder rheology," *Constr. Build. Mater.*, 2012, doi: 10.1016/j.conbuildmat.2011.12.022.

[13] L. Shiman, A. Shiman, N. Spitsyna, and A. Lobach, "Effects of nanocomposites on the high temperature rheological properties of a PG58 asphalt-binder," in *Geotechnical Special Publication*, 2011, doi: 10.1061/47634(413)29.

[14] Z. You *et al.*, "Nanoclay-modified asphalt materials: Preparation and characterization," *Constr. Build. Mater.*, 2011, doi: 10.1016/j.conbuildmat.2010.06.070.

[15] X. Shi, S. W. Goh, M. Akin, S. Stevens, and Z. You, "Exploring the interactions of chloride deicer solutions with nanomodified and micromodified asphalt mixtures using artificial neural networks," *J. Mater. Civ. Eng.*, 2012, doi: 10.1061/(ASCE)MT.1943-5533.0000452.

[16] C. Fischer, S. A. Braun, P. E. Bourban, V. Michaud, C. J. G. Plummer, and J. A. E. Månson, "Dynamic properties of sandwich structures with integrated shear-thickening fluids," *Smart Mater. Struct.*, 2006, doi: 10.1088/0964-1726/15/5/036.

[17] B. J. Maranzano and N. J. Wagner, "Flow-small angle neutron scattering measurements of colloidal dispersion microstructure evolution through the shear thickening transition," *J. Chem. Phys.*, 2002, doi: 10.1063/1.1519253.

[18] W. H. Boersma, J. Laven, and H. N. Stein, "Computer simulations of shear thickening of concentrated dispersions," *J. Rheol. (N. Y. N. Y).*, 1995, doi: 10.1122/1.550621.

[19] T. Tian, "Study of shear thickening / stiffened materials and their applications Study of Shear thickening / stiffened materials and their applications," 2016.

[20] J. Zhu, B. Birgisson, and N. Kringos, "Polymer modification of bitumen: Advances and challenges," *Eur. Polym. J.*, vol. 54, no. 1, pp. 18–38, 2014, doi: 10.1016/j.eurpolymj.2014.02.005.

[21] E. H. Fini, P. Hajikarimi, M. Rahi, and F. M. Nejad, "Physiochemical, Rheological, and Oxidative aging characteristics of asphalt binder in the presence of mesoporous silica nanoparticles," *J. Mater. Civ. Eng.*, 2016, doi: 10.1061/(ASCE)MT.1943-5533.0001423.

[22] M. Faramarzi, M. Arabani, A. K. Haghi, and V. Motaghitalab, "A Study on the Effects of CNT's on Hot Mix Asphalt Marshal-Parameters," no. March, pp. 1–9, 2013.

[23] R. Atif and F. Inam, "Reasons and remedies for the agglomeration of multilayered graphene and carbon nanotubes in polymers," *Beilstein J. Nanotechnol.*, 2016, doi: 10.3762/bjnano.7.109.

INFLUENCE OF BANANA FIBERS ON ASPHALT BINDER

[a]Junaid Khan, [b]Syed Bilal Ahmed Zaidi, [c]Naveed Ahmad, [d]Akhlaq Aman
Department of Civil Engineering, University of Engineering and Technology Taxila
a: mjunaidkhan729@gmail.com
b:bilal.zaidi@uettaxila.edu.pk
c: n.ahmad@uettaxila.edu.pk
d: akhlaqaman13@gmail.com

Abstract- The application of natural fibers as a modifier in the asphalt binder has been extensively increased due to their environment and economic friendly extraction. In this study, banana fibers of 6mm length have been used to prepare modified asphalt binder with three different dosages of 2, 4 and 6% by weight of binder. The effect of banana fibers on various binder properties was investigated by conducting a combination of conventional and rheological testing which includes penetration, softening point, ductility, performance grading and frequency sweep tests. The study concludes that penetration and ductility of modified asphalt binder decreases but the softening point increases with the increase in the percent dosages of banana fibers. The shear modulus improved significantly with an increased dose of fibers which concludes that banana fibers made the asphalt binder harder, stiffer and improved its resistance to high temperature performance.

Keywords- Banana Fibers, Asphalt Binder, Performance Grading, Dynamic Shear Rheometer.

1 INTRODUCTION:

Bitumen is used as an asphalt binder in the flexible pavements. It is a viscoelastic material and its behavior is very sensitive to the temperature. The unmodified bitumen which is supplied from the refineries does not perform well in the extreme temperatures [1]. In summer, especially in the areas of high temperature, it becomes too soft to be used for paving and fails prematurely because of rutting [2]. To tackle this problem one way is binder modification.

There are different modifiers have been used in the bitumen which includes polymers, waste materials, hydrocarbons, extenders and fibers [3]. Fibers can be extracted from natural or can be made artificially. Naturally, the origin of the fiber may be an animal, mineral or a plant. It can be extracted from the different seeds, stem or leaves of the plant. Natural fibers are environment friendly and cheaper.

It has been concluded that each type of fiber enhance some of properties of asphalt binder depending upon the mixture properties [4]. The study showed that the penetration value of fiber modified bitumen binder gets decreased and at the same time the softening point becomes increased with the inclusion of fiber in the bitumen binder [5]. The shear modulus and resistance to flow of bitumen binder also enhanced [6]. The behaviour of asphalt in term of cracking and rutting become enhanced. The resilient modulus has been improved after the inclusion of fiber modification of asphalt binder [7]. The fatigue properties of asphalt mixture were significantly improved [8]. The mechanical properties of the asphalt mixture were improved by the addition of fiber as a modifier [9]. Fiber reinforcement improved the resistance to flow and rutting of asphalt mixture [5]. Ceramic fiber increases the viscosity and decreases the workability of asphalt binder [10]. The glass fiber modified asphalt showed more resistance to crack initiation comparative to the unmodified asphalt [11]. Natural fiber modified asphalt showed improved high temperature performance [12]. [13] Bamboo modified asphalt showed enhance behavior in low temperature cracking and also in term of rutting.[14][15]. In this study Banana fibers, which have been extracted from the stem of the banana plant used as a modifier in the bitumen

Previously, banana fiber used in SMA in different lengths and fixed content of 0.3% by weight of asphalt binder [15]. In this study the influence different dosages of banana fiber on asphalt binder in length 6mm has been studied.

The objective of this study is to evaluate the effect of banana fiber on the asphalt binder considering conventional and rheological properties.

2 MATERIALS AND METHODS

2.1 *Materials*

The base bitumen of PG58 used in this study has been supplied by the Attack refinery limited (ARL). Banana fibers were supplied and cut into a length of 6mm by a local manufacturer. To ensure that fiber is moisture was first placed in the oven at the temperature of 105 ±10ºC and then the weight difference after every 2 hours until the become insignificant. The mixing of banana fiber with bitumen binder was done through a shear mixer of 1500 rpm [9].

3 TEST METHODS

3.1 *Conventional Testing*

Conventional techniques which include penetration test, softening point test and ductility test have been used with base bitumen and fiber modified bitumen. Penetration test was performed according to the ASTM D5 . The softening point test was performed using the ring and ball apparatus according to ASTM D36. The ductility test which represents the length of elongation shown by the bitumen samples when the tensile pull is applied was carried out in accordance with ASTM D13.

3.2 *Rheological testing*

Performance grading of base and modified asphalt binder were studied through Dynamic shear rheometer according to AASHTO T15 with 25 mm geometry under strain controlled at 10HZ. Frequency sweep test was also carried to investigate the rheological characteristics of base and modified asphalt binder under temperature ranges (58°C, 64°C, 70°C and 82°C) under strain controlled condition. The data obtained from the test was used as input in a sigmoidal function to create a master curve at a reference temperature of 58ºC [16].

4 RESULTS

4.1 *Conventional test results:*

The result of penetration, softening point and ductility test results of base and modified asphalt binder has been shown in figure 1 which concludes that with banana fiber modification the penetration and ductility of asphalt binder decreases while at the same time increase in the softening point has been observed. The decrease in the penetration and ductility values indicates that asphalt binder becomes hard and stiff with the fiber modification. Moreover, the elevation in softening point shows that temperature susceptibility gets reduced. These results reflect that high temperature performance of asphalt binder has been improved by the inclusion of banana fiber.

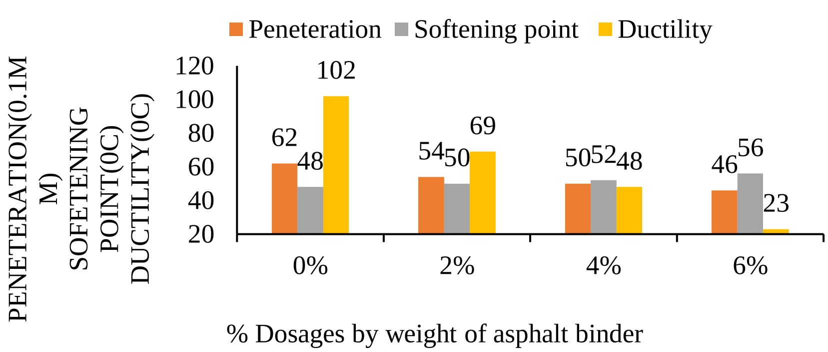


Figure 12 Conventional Test results

4.2 Rheological testing

4.2.1 Performance Grading:

The effect of banana fiber on the performance grading of asphalt binder has been studied through dynamic shear rheometer. The test results presented in figure 2 reveals that with the inclusion of banana fiber the PG of asphalt binder significantly improved.

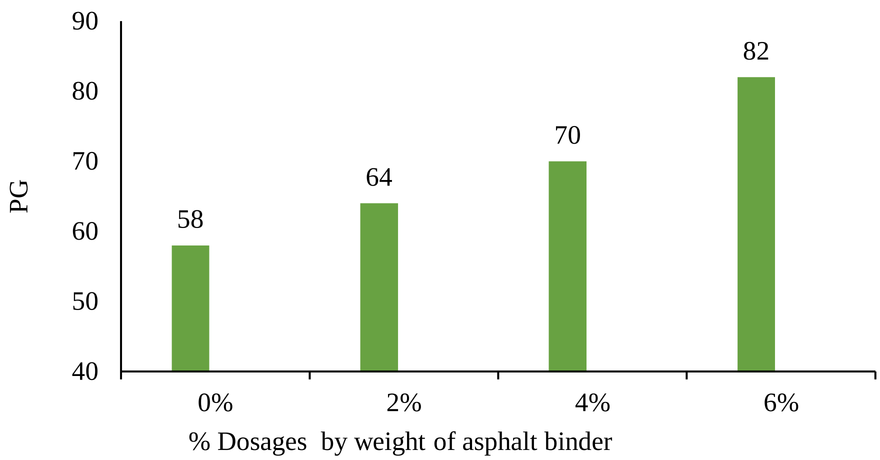


Figure 65 Performance Grading

4.2.2 Frequency sweep test:

The effect of banana fiber on rheological properties of asphalt binder was also studied through the frequency sweep test which concludes that modified asphalt binder has greater G^* values as comparative to the bases asphalt binder. The test result has been shown in figure 3 which indicates that with the modification the asphalt binder becomes stiffer and as a result, the capability the resistance to the permanent deformation has increased.

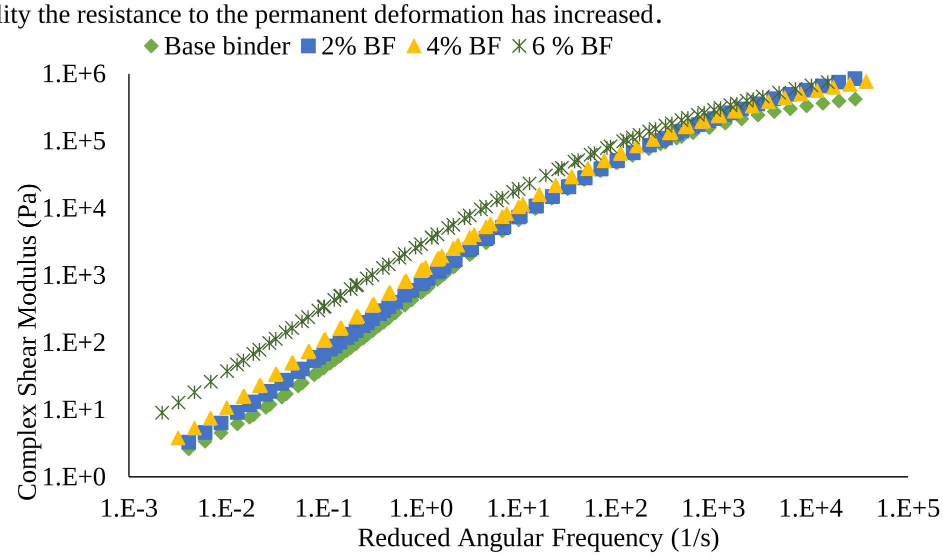


Figure 66 Result of Frequency Sweep Test

4.3 Recommended Fiber content:

The fiber content of 4% has been recommended based on test results. With the increase in the percentage of fiber content, the stiffness of asphalt binder increases and 6% dosage of banana fiber content makes the asphalt binder significantly stiff which may cause the abrupt failure of asphalt binder. Moreover, the modified binder prepared with 4% dosage has a PG 70 grade which is considered suitable considering climatic conditions of Pakistan where average temperature lies between 0^oC and 50^oC [17].

5 CONCLUSION

In this study fiber extracted from the banana plant has been used as a modifier in asphalt binder. The effect of banana fiber modification in asphalt binder was investigated by a combination of conventional and rheological test techniques. The test results reflects that asphalt binder become stiffer and improvement in the complex shear modulus with the increase of percent dosage of BF this concludes that the modified asphalt binder can perform well in the high temperature area and can enhance the distresses in the pavement. Moreover, BF has been obtained from the natural source so it is an economic and environment friendly modifier.[15]The conclusion which can be drawn based on the test results from this study are as follows:

- Asphalt binder modification with the banana fiber decreases the penetration and ductility values. This shows that asphalt binder has become harder and stiffer with this modification.
- With the increase in the dosage of banana fibers in asphalt binder, its softening point also increases which reveals that temperature susceptibility of asphalt binder decreases.
- A significant improvement in the complex shear modulus was observed in the asphalt binder modified with fibers in comparison to the base binder.
- Fiber content of 4% has been recommended based on test results and local conditions.

REFERENCES:

[1] N. Akmal, "Application of asphalt-containing materials. Polym News,," vol. 24, pp. 136–4., 1999.
[2] J. Rafi et al., "performance evaluation of carbon black nano-particle reinforced asphalt mixture,," Appl. Sci, vol. 8 doi:10.3390/app8071114, 2018.
[3] O. S. Abiola, W. K. Kupolati, and E. R. Sadiku, "Utilisation of natural fibre as modifier in bituminous mixes: A review," Construction and Building Materials, vol. 54, pp. 305-312, 2014.
[4] C. J. S. Acevedo, P. L. González, P. P. Muñoz, and D. C. Fresno, "Mechanical performance of fibers in hot mix asphalt: A review," Construction and Building Materials, vol. 200 pp. 756–769, 2019.
[5] S. M. Abtahi and S. M. Hejazi;, "Fiber-reinforced asphalt-concrete – A review.," Construction and Building Materials, vol. 24, pp. 871–877., 2010.
[6] H. Chen, "Experimental study of fibers in stabilizing and reinforcing asphalt binder," vol. 89 pp. p. 1616–1622., 2010.
[7] H. Ziari and A. Moniri, "Laboratory evaluation of the effect of synthetic Polyolefin-glass fibers on performance properties of hot mix asphalt.," Construction and Building Materials, vol. 213 pp. 459–468, 2019.
[8] Q. Ye, S. Wu, and N. Li, "Investigation of the dynamic and fatigue properties of fiber-modified asphalt mixtures," International Journal of Fatigue, vol. 31 pp. 1598–1602, 2009.
[9] L. Xiaoming and W. Shaopeng, "Study on the graphite and carbon fiber modified asphalt concrete," Construction and Building Materials, vol. 25 pp. 1807–1811, 2011.
[10] M. Arabani and A. Shabani, "Evaluation of the ceramic fiber modified asphalt binder," Construction and Building Materials, vol. 205 pp. 377–386, 2019.
[11] S. H. Khanghahi and A. Tortum, " Determination of the optimum conditions for gilsonite and glass fiber in HMA under mixed mode I/III loading in fracture tests.," J. Mater. Civ. Eng, vol. 30 2018.
[12] Y. Sheng, B. Zhang, Y. Yan, H. Li, Z. Chen, and H. Chen, "Laboratory Investigation on the Use of Bamboo Fiber in Asphalt Mixtures for Enhanced Performance," Arabian Journal for Science and Engineering, 2018.
[13] L. M. G. Klinsky, K. E. Kaloush, V. C. Faria, and V. S. S. Bardin, "Performance characteristics of fiber modified hot mix asphalt," Construction and Building Materials, vol. 176 pp. 747–752, 2018.
[14] J. Gao, H. Wang, C. Liu, D. Ge, Z. You, and M. Yu, "High-temperature rheological behavior and fatigue performance of lignin modified asphalt binder,," Construction and Building Materials,, vol. 230 p. 117063, 2020.
[15] L. F. Costa, L.C. d. F. L. Lucena, A. E. d. F. L. Lucena, and A. G. d. Barros, "Use of Banana Fibers in SMA Mixtures," J. Mater. Civ. Eng,, vol. 32, p. 04019341, 2019.

[16] A. Aman, I. Hafeez, M. Zubair, and S. B. A. Zaidi, "Influence of phosphorous methyl compound on asphalt binder," International Journal of Pavement Engineering, 2020.
[17] M. W. Mirza, Z. Abbas, and M. A. Rizwi, "Temperature Zooning of Pakistan for Asphalt Mix Design," Pak. J. Eng.Appl. Sci, vol. 8, pp. 49–60., 2011.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

THE EFFECT OF USING POLYPROPYLENE FIBER ON DEFORMATION RESISTANCE OF ASPHALT CONCRETE

[a] Muhammad Fawad Rashid, [b] Naveed Ahmed, [c] Ahtsham Ahmed
a: Department of Civil Engineering, University of engineering and Technology Taxila fawad04ce2k14@gmail.com
b: Department of Civil Engineering, University of Engineering and Technology Taxila, n.ahmad@uettaxila.edu.pk
c: Department of Civil Engineering, University of Engineering and Technology Taxila, iamahtsham@gmail.com

Abstract- Asphalt concrete (AC), a mixture of bitumen and aggregates is one of the widely used material in Civil Engineering with an approximate worldwide usage of 102 million tons annually. Since the pavement construction is only expected to increase with time, scientists and engineers have been putting great effort into improvement of the performance of asphalt pavements from both the functional and sustainability perspectives. Binder has been of special focus in this regard and has been modified with the addition of various fibers in one of the recognized techniques to improve the Asphalt Concrete. Fibers modified asphalt is referred to as Fiber-Reinforced Asphalt-Concrete (FRAC). One key fiber that has shown promising outcomes is polypropylene fiber. In this study, we investigated FRAC materials modified by polypropylene fiber inclusion and its effect on the deformation resistance. The Effects of modification were also observed on the mixing procedure. Results showed that the Optimum Binder Content increases 10-11% and the stability of the polypropylene fiber modified asphalt pavement increases up to 14% however, the flow values decrease up to 7-8%. Addition of polypropylene fibers significantly improved the deformation resistance of asphalt. In addition to achieving the asphalt mechanical improvement through polypropylene fibers lead to the concept of a new market to utilize the waste fiber thereby lessening the environmental consequences.

Keywords- Asphalt Concrete, Fiber-Reinforced Asphalt Concrete (FRAC), Polypropylene Fiber.

1 INTRODUCTION

Intra country transport communication is so vital that it has become one of the integral functions of both economic stability and progress. However, pure, and unmodified asphalts used in Pakistan are prone to temperature cracking due to weather extremities. Other distresses like alligator or fatigue cracking and rutting are also seen on the roads in Pakistan due to improper mix-design and inadequate compaction. A resultant penetration of water is caused by these distresses leading to partial or complete pavement-failure, making it necessary to improve the properties of pavement. Being a viscoelastic material, pavement performance such as rut resistance owes itself greatly to bitumen. In hot weather extremes problem is aggravated due to bitumen's lower stiffness [1].

These limitations call for research and innovation in materials and techniques and innovations in pavement engineering to advance the pavements in terms of durability and resistance to distresses and thereby requiring lesser maintenance [2]. The research to achieve these goals has culminated into development of the techniques that are collectively known as 'modification of asphalt' [3]. They employ various types of fibers and polymers that are applied to the asphalt [4]. Fiber application is very advantageous for increased durability as it improves fatigue and rutting resistance, increases service life, and reduces thermal cracking [2, 5]. In conventional mixes, Fiber-reinforced asphalt concrete materials (FRAC) materials are used for overlays or maintenance of pavements and bridge-deck membranes. They are also used in composite pavements and multi-course flexible pavements [6].Test like Indirect Tensile Test (IDT), Marshall Stability, susceptibility to moisture damage, susceptibility to freeze/thaw, modulus of resilience, and deformation under repeated load performed by Simpson and Kamyar after modifying the mix by adding polyester fibers, polypropylene, and some other polymer sand showed an increased tensile strength and cracking resistance for polypropylene-modified mixtures of polymers. Under repeated load deformation test, rutting potential was observed to reduce only in polypropylene-modified specimens [7].

Polypropylene addition into the asphalt concrete in a dry basis increases Marshall stability values, decreases flow values and increases the fatigue life in a marked way [8]. Stiffness of bitumen also increases with the addition of *polypropylene fibers* resulting in more stiff mixtures with reduced drain-down and increased fatigue life [9]. Another research shows that addition of *polypropylene* into asphalt has shown the decrease in the Marshal Flow (38%), increase in stability values (26.3%) and increase in air voids (67.5%) [10]. As far as the bonding and strengthening of bitumen is concerned, polypropylene fibers depict excellent results [11]. Also, for consistent fiber lengths at lower temperature, higher fiber contents have shown higher strengths and fracture toughness [12]. Earlier, limitations have been showed in the mixing process of polypropylene fibers using dry method [13]. This study use different percentages of polypropylene fiber incorporating small size (i.e. 6mm) to explore the impact of smaller fiber size on dry mixing process [14]. Marshal Stability test was performed for flow and stability values to investigate polypropylene fiber's impact on Optimum Binder Content (OBC) and to find resistances against distresses in asphalt concrete.

1.1 Polypropylene Fiber

Polypropylene is a 100 percent synthetic fiber formed of 85 percent of monomer 'propylene (C_3H_6)' which is a hydrocarbon. Having high molecular weight and mode, the propylene polymerizes to produce polypropylene fibers with very useful properties like lowest density, less moisture absorption, excellent resistant to chemicals, acids and alkalis, and lower conductivity in comparison to other synthetic fibers. Different types of polypropylene fibers classified based on length, diameter, density, and strength (Modulus of elasticity) are shown in Table 1.

Table 1 - Different types of polypropylene fiber **[15]**

Fiber type	Length (mm)	Diameter (mm)	Tensile strength (MPa)	Elastic modulus (GPa)	Specific surface area (m^2/kg)	Density (kg/cm^3)
Mono-filament	30 - 50	0.30 - 0.35	547 - 658	3.50 - 7.50	91	0.90
Micro-filament	12 - 20	0.05 - 0.20	330 - 414	3.70 - 5.50	225	0.91
Fibrillated	19 - 40	0.20 - 0.30	500 - 750	5.00 - 10.00	58	0.95

Asphalt modification with addition of polypropylene fiber shows higher performance grade for rutting resistance at increased temperature. Also, this modification reduces the susceptibility of asphalt to changes in temperature. Additionally, benefits like drain down prevention and improved fatigue performance by enhancing crack resistance of asphalt material are also achieved.

2 RESEARCH METHODOLOGY

Initially, aggregate to be used for the project was selected and brought from Margalla stone quarry. Then the bitumen grade of 60/70 was selected. Based on material properties, a fine gradation of NHA class B was preferred over the NHA class A gradation. After having performed the requisite testing on the materials, the challenge to prepare mix and to select percentage of fibers for Marshal Mix Design was overcame by reviewing the literature. The dosages of 0.5% and 1.0% were selected by weight to determine Optimum Binder Content through Marshal Mix Design, after studying various studies. After OBC determination, sample of slab was prepared for indirect tensile test separately for control mix and reinforced fiber mix for performance analysis. Dry method was used to mix the fibers with aggregate and bitumen. In the end, a comparison was drawn for different results obtained from unmodified, 0.5% polypropylene modified and 1% polypropylene modified asphalt concrete. A conclusion was drawn through experimental results.

3 EXPERIMENTAL DETAILS

Various type of tests performed on the aggregate, bitumen and asphalt concrete mixtures have been discussed. For this study, Class B aggregate of NHA Specification was used because it is easy to make a comparison of the test results in case of fine classifications. The physical properties of the aggregate and bitumen used in this study are listed in Table 2. Dry method has been used in this study to add the polypropylene fibers into the asphalt concrete mixture as this method has been well established among the researcher for the successful addition of polypropylene fibers into the asphalt mixture [2, 10, 16]. In dry method, fibers are added to the pre-heated aggregate in accordance with ASTM-D1559 standard. After this, bitumen is added to the aggregate & fiber mixture gradually and Marshall Mix design test is performed on unmodified and polypropylene modified asphalt concrete samples to select suitable type of aggregate and corresponding economical asphalt binder content. This recommended mixture is known as job-mix formula (JMF).

3.1 *Sample Preparation.*

Minimum requirement of NHA is of 3.5 percent of asphalt content by weight of the total mixture for Class A and Class B. Normally, bitumen in 3 to 6 percent by total weight of mixture is added for the OBC determination. Mixture for fiber-modified and unmodified mixtures was prepared for 3.5, 4.0, 4.5, 5.0, and 5.5% asphalt. Three samples, two compacted and one loose one with a total weight of each sample 1200g are prepared. 0.5% (6g) and 1.0% (12g) fiber by weight of the total sample were added. Compacted samples were prepared at first by the dry method and after being placed in testing mould, 75 blows on each side were subjected using hammer of 4.5 kg. Resultant sample was cylinder with 4-inches inner diameter and 2.5 inches height. Mixture was then prepared for the loose sample with no compaction effort (Blows). Calculation of values different parameters was the performed using the formulae listed in Table 3.

Table 2 - Physical properties of the aggregates and bitumen

Aggregates			**Bitumen**		
Source		Margalla stone quarry	**Test Name**	**Value**	**ASTM Standard**
Type		100 % crushed	Penetration Test (25°C)	60 - 70	ASTM D5
Los-Angeles Abrasion Value		24.92 %	Flash point	146°C	ASTM D92
Soundness	Coarse aggregate	3.10 %	Softening point	48°C	ASTM D36
	Fine aggregate	4.60 %	Ductility (5cm / min)	> 100 cm	ASTM D113
Elongation Index		2.90 %	Specific gravity	1.034	ASTM D70
Flakiness Index		5.80 %			
Sand Equivalent		72 %			

Table 3 – Different parameters for Marshal Stability Test

Bulk specific gravity of aggregates, $\boldsymbol{G_{sb}}$	$G_{sb}=\dfrac{P_1+P_2+\cdots\cdots+P_N}{\frac{P_1}{G_1}+\frac{P_2}{G_2}+\cdots\cdots+\frac{P_N}{G_N}}$	Voids in Mineral Aggregates, VMA	$VMA=100-\dfrac{G_{mb}\times P_s}{G_{sb}}$
Effective specific gravity of aggregate, $\boldsymbol{G_{se}}$	$G_{se}=\dfrac{P_{mm}-P_b}{\frac{P_{mm}}{G_{mm}}-\frac{P_b}{G_b}}$	Air voids, $\boldsymbol{V_a}$	$V_a=100\times\dfrac{G_{mm}-G_{mb}}{G_{mm}}$
Effective Asphalt Content, $\boldsymbol{P_{be}}$	$P_{be}=P_b-\dfrac{P_{ba}}{100}\times P_s$	Voids filled with asphalt, VFA	$VFA=100\times\dfrac{VMA-V_a}{VMA}$

3.2 *Determination of stability using Marshall Stability and Flow Test.*

Stability maybe defined as the maximum load resistance of the sample and flow is defined as the deformation corresponding to maximum load (Stability) at standard temperature of 60°C. For determining stability, compacted Marshall samples are kept in the water bath at 60°C ±1°C temperature for 30 to 40 minutes and then tested in Marshall Stability tester. Loading is applied on the specimen at constant rate of 51 millimeters per minute, until sample fails. Total number of Newton (lbs.) or kgs force at which sample fails is recorded as Marshall Stability value. Deformation corresponding to this force is recorded as flow and expressed in units' of 1/100 inches.

a)  b)  c)  d) 

Figure 1: a. Polypropylene fibers before addition. b. Polypropylene-fiber modified sample being prepared. c. Compacted and loose samples ready for Marshall stability test. d. Polypropylene-fiber modified samples after Stability test

3.3 *Calculation of Optimum Binder Content.*

After calculations six graphs are plotted between asphalt content on x-axis and unit weight, VMA, VFA, V_a, flow, and stability on y-axis. Of the various methods used worldwide to find out Optimum Binder Content are used worldwide, one is to use following three graphs against mentioned criteria for the calculation of optimum asphalt content (a) Bitumen-content against maximum stability (b) Bitumen-content against maximum unit-weight (c) Bitumen-content against 4% air voids. Average of all three asphalt contents obtained from above three graphs is reported as optimum asphalt content (OAC) or optimum bitumen content (OBC).

4 RESULTS

The results of various tests performed on the asphalt concrete mixtures and their analysis, have been discussed. Results of three kind of asphalt concrete mixtures were tabulated. Graphs between unit weight, VMA, VFA, V_a, stability and flow against asphalt content have been plotted. For modified mixture, results showed in Table 4 reveal that the optimum binder content's value increases by adding polypropylene fiber. Also, stability of the mixture increases, and flow decreases as compared to unmodified samples.

Table 4 - Optimum binder content of unmodified and Polypropylene modified mixtures

Criteria	Unmodified		Polypropylene Modified			
			Fiber percent		OBC	
		OBC	0.5	1.0	0.5	1.0
Bitumen-content against maximum stability	4.5	4.57	4.5	4.45	5.08	5.05
Bitumen-content against maximum unit-weight	4.7		5.5	5.5		
Bitumen-content against 4% air voids	4.5		5.25	5.2		

Figure 2 to Figure 4 show graphical plot between asphalt content and various parameters of Marshall test for unmodified and fiber modified asphalt mixtures. Stability of the polypropylene fibers samples is more when compared to the unmodified or control samples with 0.5% PP-fiber modification being more stable than 1.0% PP-fiber modified asphalt mixture, meaning that low polypropylene fiber content can achieve greater stability as compared to higher one. Flow values of polypropylene modified samples are less than those of control samples which means modified samples are more stable against the traffic loads.

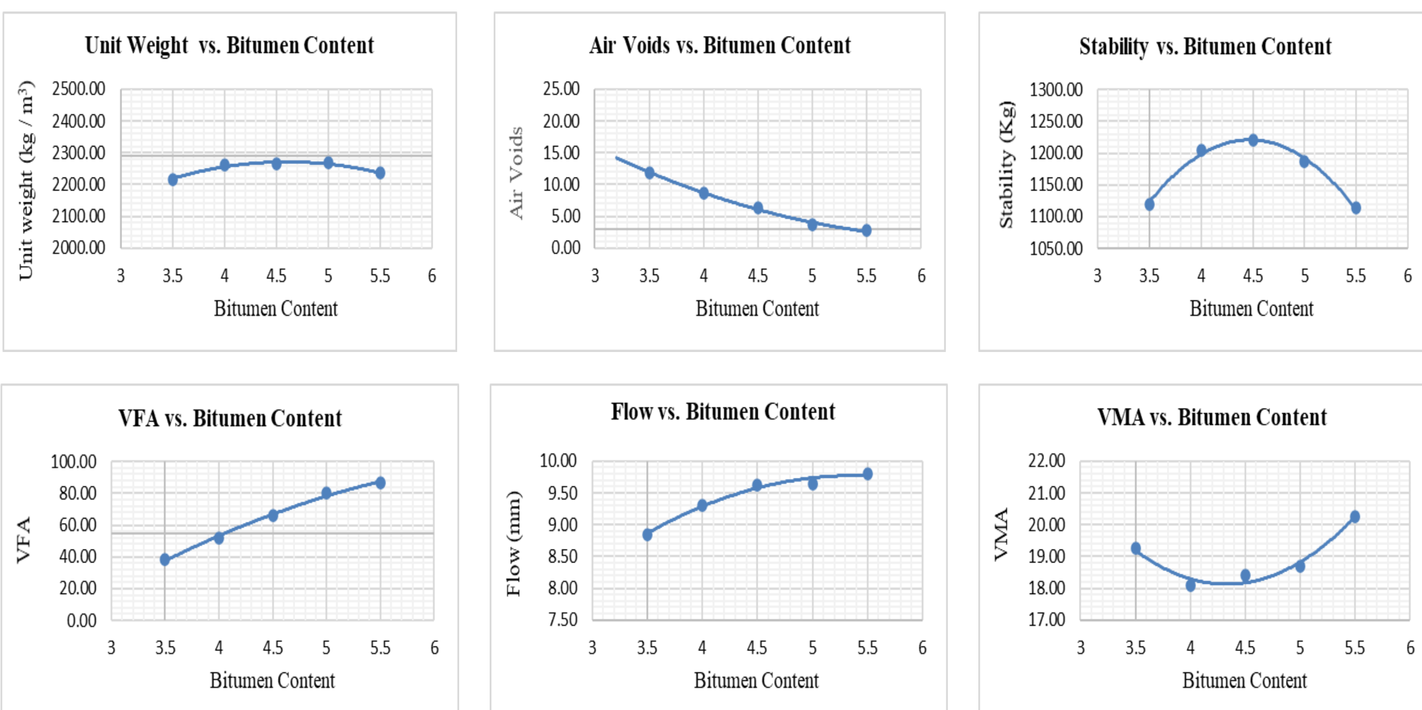


Figure 2 – Graphs for unmodified mixture

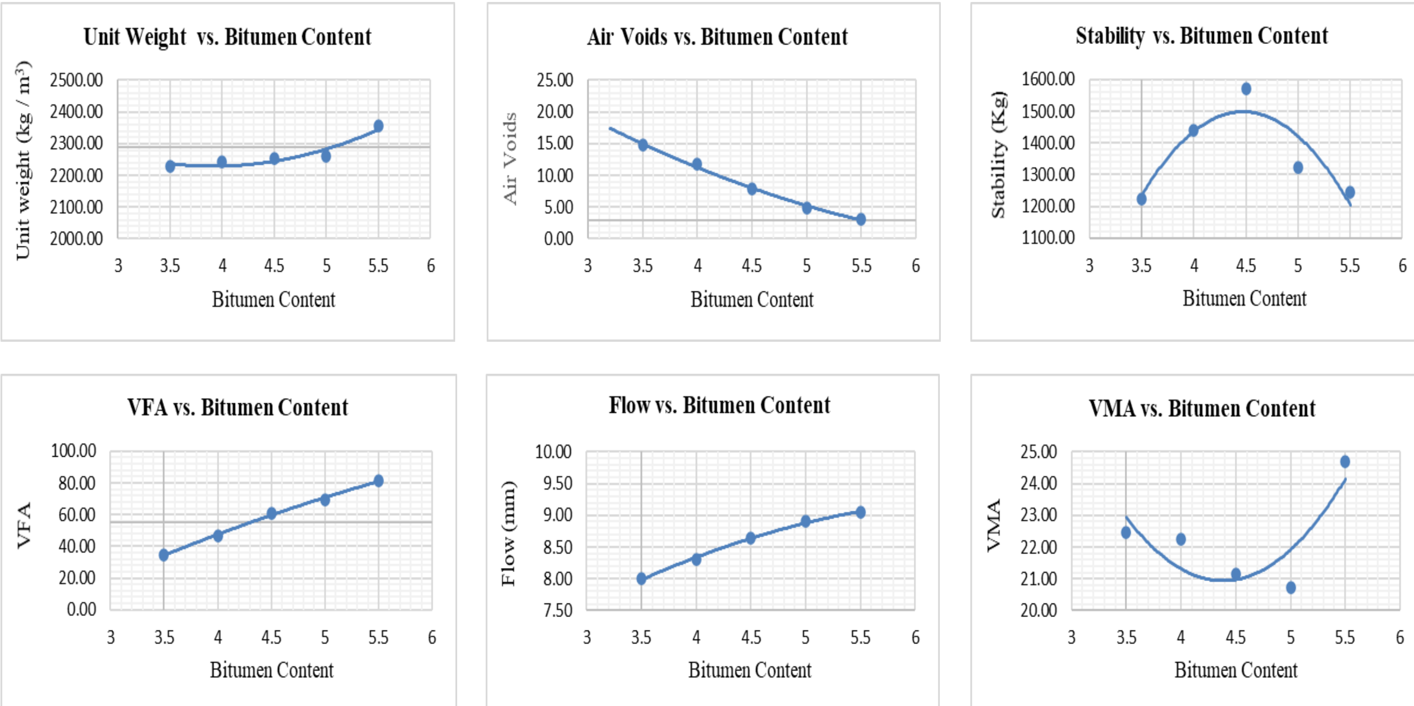


Figure 3 – Graphs for 0.5% polypropylene modified mixture

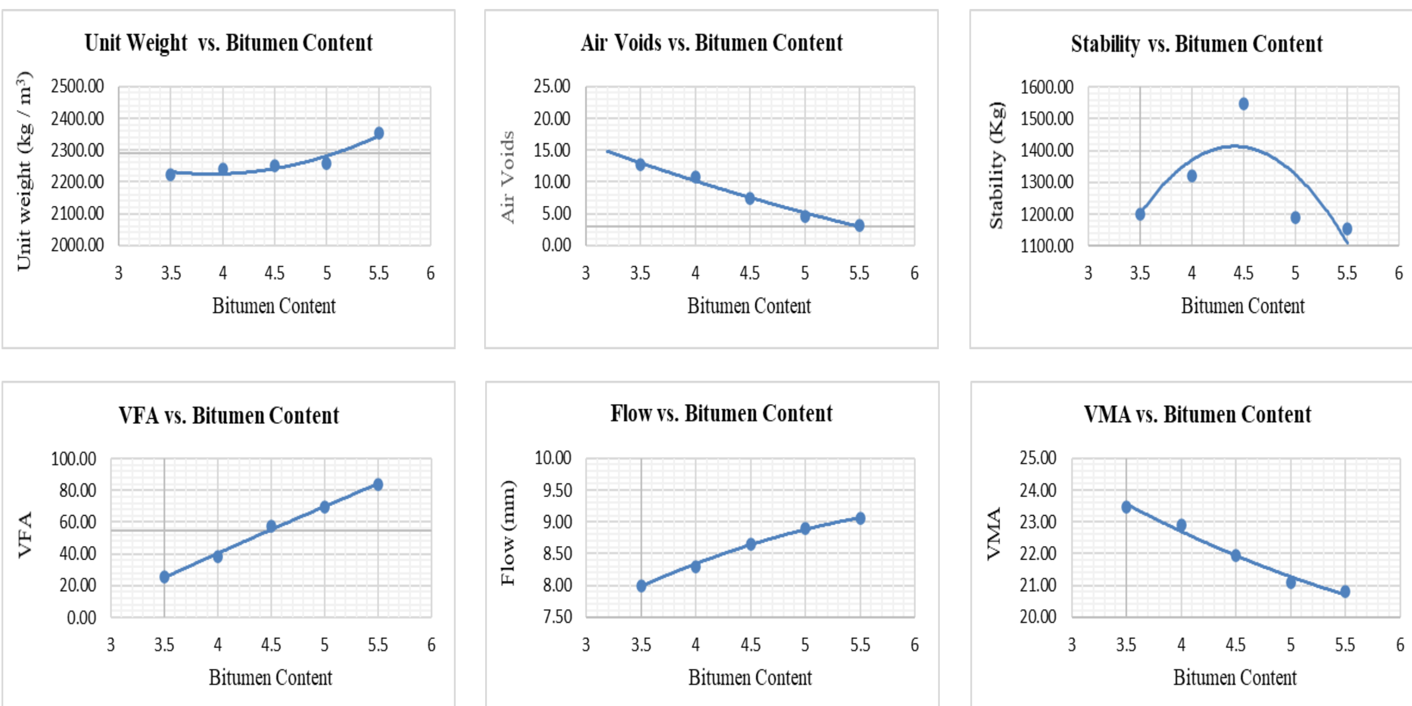
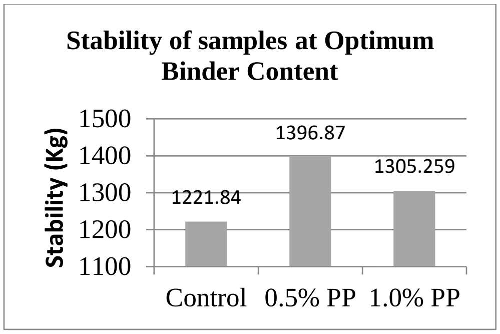


Figure 4 – Graphs for 1.0% polypropylene modified mixture

Figure 5a reveals the stability of 0.5% polypropylene fiber modified sample is highest among all other samples at OBC while Figure 5b shows minimum flow at optimum asphalt content in case of 0.5% PP-modified samples as compared to other samples. Also, mix-design criteria at optimum binder content is also verified for control and PP-modified samples.



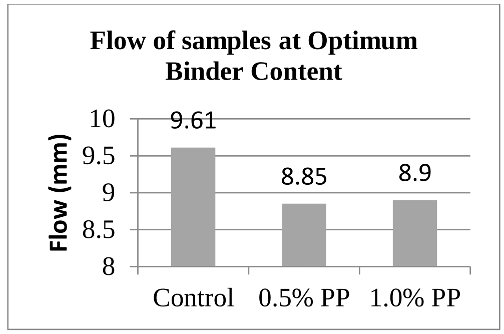


Figure 5 – a. Stability of the control & modified samples at OBC. b. Flow of the control & modified samples at OBC

5 CONCLUSION

In this study, polypropylene fibers were used as modification in asphalt concrete. Main purpose of this research was to study the effect of the fiber addition in dry method in the asphalt mixture and the performance of hot mix asphalt. 0.5% and 1.0% by weight polypropylene fiber was added to asphalt mixture for the analysis. It is concluded from the results that polypropylene fibers modification has improved various properties of the HMA. For example, polypropylene addition significantly improved the stability of the asphalt mixture up to 14% and Optimum Binder Content up to 10-11%. With polypropylene fiber addition, VFA, overall unit weight, air voids and flow decreased in comparison to unmodified asphalt mixture. Modified mixture gave best performance at 0.5% polypropylene fiber.

ACKNOWLEDGMENTS

The authors would like to thank Muhammad Asad Hayat and Muhammad Farhan Ahsan who helped thorough out the experimental work, particularly TITE department, UET Taxila for providing laboratory assistance.

REFERENCES

[1] A. Arshadi, "Importance of asphalt binder properties on rut resistance of asphalt mixture," 2013.
[2] A. Qadir, "Rutting performance of polypropylene modified asphalt concrete," *International Journal of Civil Engineering,* vol. 12, pp. 304-312, 2014.
[3] S. Tapkın, Ü. Uşar, A. Tuncan, and M. Tuncan, "Repeated creep behavior of polypropylene fiber-reinforced bituminous mixtures," *Journal of Transportation Engineering,* vol. 135, pp. 240-249, 2009.
[4] Y. R. Kim, *Modeling of asphalt concrete*, 2008.
[5] G. D. Airey, "Fundamental binder and practical mixture evaluation of polymer modified bituminous materials," *International Journal of Pavement Engineering,* vol. 5, pp. 137-151, 2004.
[6] J. Echols, "New mix method for fiber-reinforced asphalt," *Public Works,* vol. 119, 1989.
[7] A. L. Simpson and K. C. Mahboub, "Case study of modified bituminous mixtures: Somerset, Kentucky," in *Infrastructure: New Materials and Methods of Repair*, 1994, pp. 88-96.
[8] S. Tapkın, "The effect of polypropylene fibers on asphalt performance," *Building and environment,* vol. 43, pp. 1065-1071, 2008.
[9] M. A. Cleven, "Investigation of the properties of carbon fiber modified asphalt mixtures," Michigan Technological University Houghton, MI, 2000.
[10] M. G. Ebrahimi, "The effect of polypropylene modification on Marshall stability and flow," Eastern Mediterranean University (EMU), 2010.
[11] J. P. Zachariah, P. P. Sarkar, B. Debnath, and M. Pal, "Effect of polypropylene fibres on bituminous concrete with brick as aggregate," *Construction and Building Materials,* vol. 168, pp. 867-876, 2018.
[12] S. Wang, R. B. Mallick, and N. Rahbar, "Toughening mechanisms in polypropylene fiber-reinforced asphalt mastic at low temperature," *Construction and Building Materials,* vol. 248, p. 118690, 2020.
[13] M. Zahedi, R. Bayat, and M. N. Jalal, "The most appropriate mixing method of polypropylene fiber with aggregates and bitumen based on binder mix design," *International Journal of Engineering & Technology,* vol. 3, p. 333, 2014.
[14] "Sika Fiber® " in *Monofilament Polypropylene Fibres* S. Pakistan, Ed., 04.06 ed, 2018.

[15] C. Saketh, J. Patel, M. Rajesh, G. Sadanand, and M. Manoj, "Statistical Analysis of Polypropylene Fiber Reinforced Concrete," *International Journal of Advance Research, Ideas and Innovations in Technology*, vol. 3, pp. 518-532, 2017.

[16] S. Esfandiarpour, "Hybrid Reinforcement of Asphalt-Concrete Mixtures Using Glass and Polypropylene Fibers," Eastern Mediterranean University (EMU), 2010.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

THE EFFECT OF USING STEEL FIBER ON DEFORMATION RESISTANCE OF ASPHALT CONCRETE

[a] Muhammad Fawad Rashid, [b] Naveed Ahmad, [c] Ahtsham Ahmed
a: Department of Civil Engineering, University of engineering and Technology Taxila, fawad04ce2k14@gmail.com
b: Department of Civil Engineering, University of engineering and Technology Taxila, n.ahmad@uettaxila.edu.pk
c: Department of Civil Engineering, University of engineering and Technology Taxila, iamahtsham@gmail.com

Abstract- *Asphalt concrete (AC*), a mixture of bitumen and aggregates is highly temperature sensitive and an equally important material used in civil engineering due to its utility and universal usage and thereby making it one of the highly researched area in the field with a focus on improving the Asphalt concrete. Of the many approaches, modification of the asphalt binder is one that focuses on addition of external agents for improving *Asphalt Concrete*. Nowadays, different materials are used to reinforce asphalt concrete. Fibers have made a reputation for themselves among the other modifiers used mainly due to the promising results that they have shown. Steel fiber modified asphalt is referred to as steel fiber-reinforced asphalt-concrete (SFRAC). This study investigates the usage of steel fiber as a modifier and its results on the deformation resistance of the *Asphalt Concrete*. The whole process was investigated carefully to observe the effects steel fiber on the mixing procedure of Asphalt Concrete during the manufacturing phase, and performance of asphalt concrete was inspected later using several laboratory tests. Results showed that the Optimum Binder Content increases 4-6% however, the stability of the steel fiber modified asphalt pavement decreases up to 20% and hence causes no significant improvement in deformation resistance. This reduction in the stability is mainly due to the insufficient bonding of the steel fiber with asphalt concrete. Whereas, from the sustainability perspective, it leads to concept of the new market to utilize waste fibers.

Keywords- Asphalt Concrete, Asphalt Mechanical Improvement, Fiber-reinforced asphalt concrete (FRAC), Steel Fiber.

1 INTRODUCTION

Intra-country transport acts as the lifeline for the trade and communication in a country. Different kinds of distresses can develop in hot-mix asphalt (HMA) which affect the structural and functional performance of pavement. In hot summers, bitumen becomes soft and when pavements are subjected to heavy loading of traffic vehicles, bitumen consolidation or lateral movement of materials take place, causing development of stresses. Above scenario necessitates research for new materials and innovations in pavement engineering to make the pavements more durable and more resistant to the distresses leading to a lesser requirement for maintenance [1]. To minimize the drastic effects of weather and traffic, various methodologies and techniques have been invented to make the performance of flexible pavements better, known as 'modification of asphalt' [2]. Various types of fibers and polymers are applied to the asphalt for this purpose [3].

It is imperative to have an idea of other research in this field before discussing the approach of this study. Nowadays, the steel fibers are used to take the stresses at the top layer of pavement which is subjected directly to the effects of loading and wear and tear [4]. Other studies on distribution of steel wool have revealed that a poor distribution is achieved when long and thin fibers are used. On the contrary, short, and thick fibers have shown better dissemination in the mixture. The impact of steel on properties like the porosity and electrical conductivity of dense asphalt concrete has also gained attention of the researchers.With regard to the particle loss resistance and flexural strength of dense asphalt concrete, no relevant improvement has been reported [5]. Recently, futuristic applications of electrically conductive asphalt concrete have been studied with a great zeal. Although it can be achieved using both the steel fiber and graphite, steel fiber has been proven to be more effective in improving the conductivity of asphalt concrete[6]. Steel fiber modified FRAP shows it as a promising material for highway pavement due to its high performance in crack regulation [7]. Cracking in low temperature, bleeding in high temperature and water damage are major contributors towards the deterioration of the pavement. The test results of rutting test, low temperature bending test, freeze-thaw splitting test have been compared with the stability in high temperature, anti-cracking performance in low temperature and the water stability between steel fiber asphalt concrete and the ordinary asphalt concrete. The conclusions drawn from these comparisons suggest that steel fiber addition in the asphalt concrete can effectively contribute towards the performance of the road [8]. Recent researches have opened a way for other promising prospects for fiber modification such as the electrothermal applications by incorporation of conductive fibres (e.g. carbon and steel fibers). Adding electrothermal properties broaden utility scope of asphalt concrete in a more futuristic way. Applications such as de-icing, snow and ice removal, self healing through induction heating, snow and ice removal and energy harvesting are some key areas in this regard [9-13]. The current work focused on increasing the lifetime and enhancing the performance of asphalt concrete roads by using steel fibers as additive material. For this purpose, Marshall test is performed using different fiber percentages and binder contents.

1.1 Steel Fiber:

Steel fibers are filaments of wire, cut to defined length, and used for the preparation of fiber-reinforced concrete, mortar, and other composite materials. Steel fibers generally have 0.3 to 1.1 mm diameter and 15 to 50 mm length. As compared to polypropylene fibers, steel fibers have very high modulus of elasticity making it a superior choice in many applications. Some of the properties of steel fibers are shown in Table 1.

Table 1 - Properties of commonly used steel fibers

Relative density	Diameter, mm (0.0001 in.)	Tensile strength, MPa	Modulus of elasticity, MPa	Strain at failure, %
7.8	100 - 1000	500 - 2600	210000	0.5 - 3.5

Although the work is still being done for developing the mixing methods of fibers with the asphalt concrete, yet the addition of short random fibers in asphalt concrete does not require much additional effort. Along with the improvisation in the mechanical performance of the asphalt pavements, the innovative prospects offered by the Steel fiber reinforced asphalt concrete (SFRAC) make it a candidate for improving sustainability and lifecycle costs.

2 RESEARCH METHODOLOGY

Initially, aggregate to be used in the project was selected. For aggregate, Margalla stone quarry was selected, and material was brought from there. Then bitumen grade was selected, and it was 60/70. Based on material properties, gradation was selected which was NHA class B which is a fine gradation as compared to NHA class A gradation. Different tests were performed for aggregates and bitumen. Next challenge was to prepare mix and select amount of fibers for Marshal Mix Design. The methodology adopted for this work is shown the figure below:

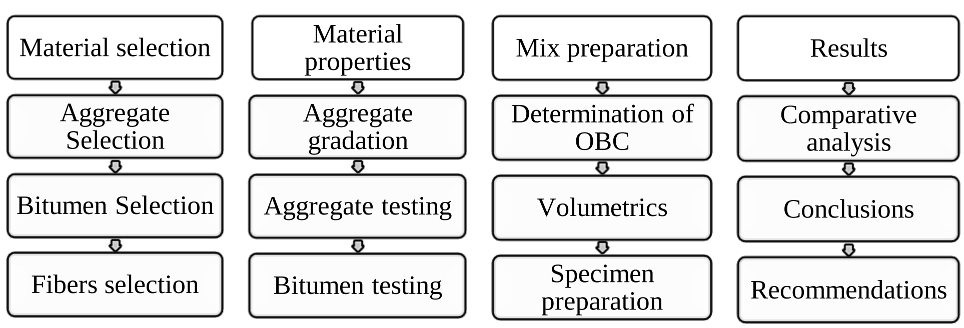


Figure 1: Scope and Methodology of the Work

Literature was reviewed to get the optimum amount of fibers for Marshall Mix Design. After reading different studies, the dosages of 0.5% and 1.0% were selected by weight to determine Optimum Binder Content through Marshal Mix Design. Dry method was used to mix the fibers with aggregate and bitumen. In the end, a comparison was drawn for different results obtained from unmodified, 0.5% steel modified and 1% steel modified asphalt concrete. A conclusion was drawn through experimental results.

3 EXPERIMENTAL DETAILS

Various type of tests performed on the aggregate, bitumen and asphalt concrete mixtures have been discussed. For this study, Class B aggregate of NHA Specification was used because it is easy to make a comparison of the test results in case of fine classifications. The physical properties of the aggregate and bitumen used are listed in Table 2.

Table 2 - Physical properties of aggregate and bitumen

Aggregate			**Bitumen**		
Source		Margalla stone quarry	**Test name**	**Value**	**Standard**
Type		100 % crushed	Penetration (25°C)	60 - 70	ASTM D5
Los-Angeles Abrasion Value		24.92 %	Flash point	146°C	ASTM D92
Soundness	Coarse aggregate	3.10 %	Softening point	48°C	ASTM D36
	Fine aggregate	4.60 %	Ductility (5cm / min)	> 100 cm	ASTM D113
Elongation Index		2.90 %	Specific gravity	1.034	ASTM D70
Flakiness Index		5.80 %			
Sand Equivalent		72 %			

Dry method has been used in this study to add the steel fibers into the asphalt concrete mixture. Reason to use the dry method is that various researchers have used this method for addition of fibers into the asphalt mixture [1, 14]. Aggregates and bitumen were pre-heated in accordance with ASTM-D1559. Steel fibers were then added gradually into the mixture. Now Marshall mix design test is performed on unmodified and steel modified asphalt concrete samples. Main objective to perform the Marshall mix design test is to select as suitable type of aggregate and corresponding economical asphalt binder content. This recommended mixture is known as job-mix formula (JMF).

3.1 *Sample Preparation.*

NHA requires minimum 3.5% of asphalt content by weight of the total mixture for Class A and Class B. Normally, bitumen in 3 to 6% by total weight of sample is added for the OBC determination. Mixture for fiber-modified and unmodified mixtures was prepared for 3.5, 4.0, 4.5, 5.0, and 5.5% asphalt. Three samples are prepared. Two compacted samples, and one loose sample. Total weight of each sample is 1200 g. 0.5% (6g) and 1.0% (12g) fiber by weight of the total mixture were added. First, compacted samples were prepared. For this, mixture was prepared by the dry method and then it was placed in the testing mould. Hammer of 4.5 kg was used for compaction dropped from a height of 18in. 75 blows are applied on both sides of the specimen. Resulted compacted sample was cylinder having 4-inches inner diameter and 2.5 inches height. Mixture was prepared for the loose sample, and no compaction effort (Blows) was applied on it. Now calculate values of different parameters by formulas listed in Table 3.

Table 3 – Different Parameters for Marshall Stability Test

Bulk specific gravity of aggregates, $\boldsymbol{G_{sb}}$	$G_{sb} = \dfrac{P_1 + P_2 + \cdots\cdots + P_N}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \cdots\cdots + \frac{P_N}{G_N}}$	Voids in Mineral Aggregates, VMA	$VMA = 100 - \dfrac{G_{mb} \times P_s}{G_{sb}}$
Effective specific gravity of aggregate, $\boldsymbol{G_{se}}$	$G_{se} = \dfrac{P_{mm} - P_b}{\frac{P_{mm}}{G_{mm}} - \frac{P_b}{G_b}}$	Air voids, $\boldsymbol{V_a}$	$V_a = 100 \times \dfrac{G_{mm} - G_{mb}}{G_{mm}}$
Effective Asphalt Content, $\boldsymbol{P_{be}}$	$P_{be} = P_b - \dfrac{P_{ba}}{100} \times P_s$	Voids filled with asphalt, VFA	$VFA = 100 \times \dfrac{VMA - V_a}{VMA}$


a) b) c) d)

Figure 2: a. Steel fibers used. b. Steel fibers after addition. c. Steel-fiber modified sample being prepared. d. Compacted and loose samples ready for Marshall Stability test

4 RESULTS

The results that were obtained from various tests performed on the asphalt concrete mixtures and their analysis, have been discussed. Results of three kind of asphalt concrete mixtures were tabulated in Table 4. Graphs between unit weight, VMA, VFA, V_a, stability and flow against asphalt content have been plotted. The results showed that with the addition of steel fibers, volume of air voids (V_a) and voids in mineral aggregates (VMA) increase with a decrease in the VFA values and unit weight of the modified mixtures in comparison to control samples.

Table 4 - Optimum binder content of unmodified and steel modified mixtures

Criteria	Unmodified		Steel Fiber Modified			
			Fiber percent		OBC	
		OBC	0.5	1	0.5	1
Bitumen-content against maximum stability	4.5	4.57	4.25	4.15	4.75	4.85
Bitumen-content against maximum unit-weight	4.7		5.5	5.5		
Bitumen-content against 4% air voids	4.5		4.5	4.5		

Graphs between asphalt content and various parameters of Marshall test for unmodified and steel fiber modified asphalt mixtures have been plotted. It is also evident from the Figure 3 to Figure 5 that steel modification has negative impact on the performance of asphalt concrete. The reason is that the stability values of steel modified samples are less as compare to those of unmodified samples and flow is more than that of unmodified samples.

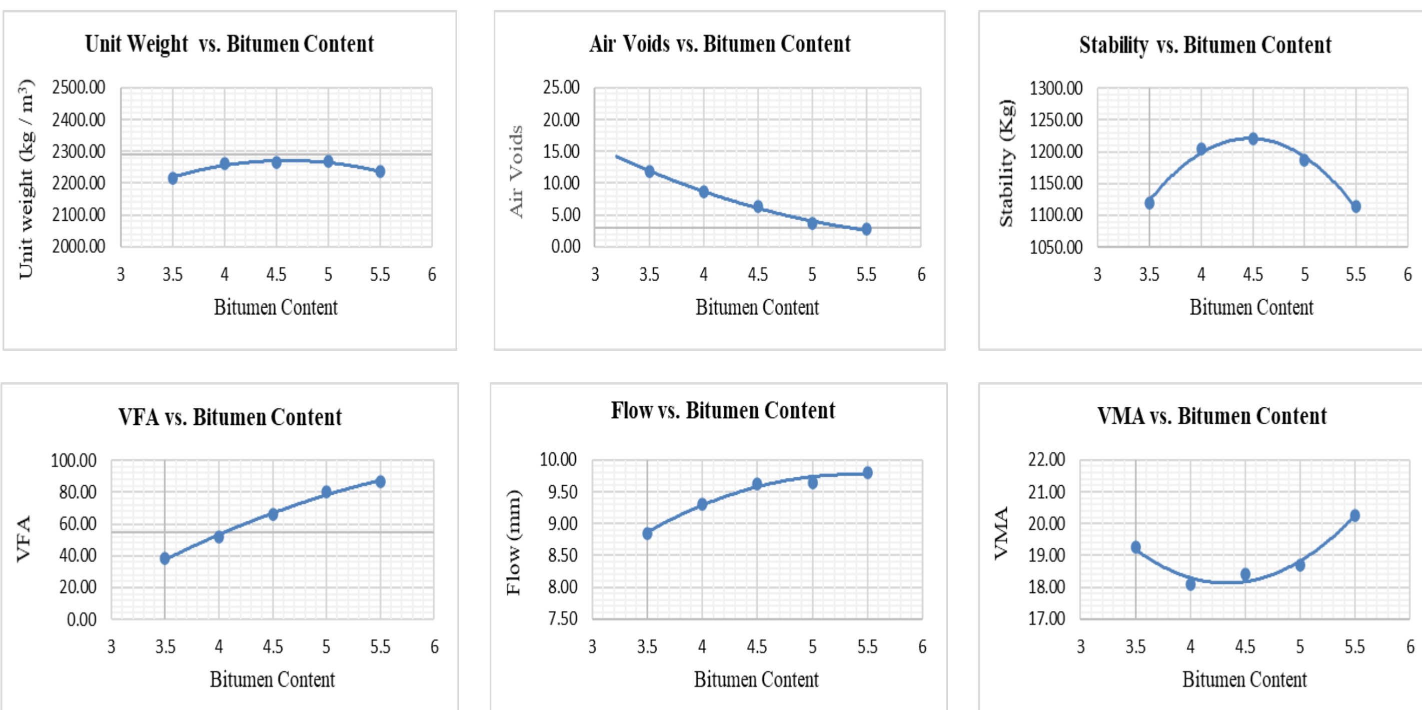


Figure 3 – Graphs for unmodified mixture

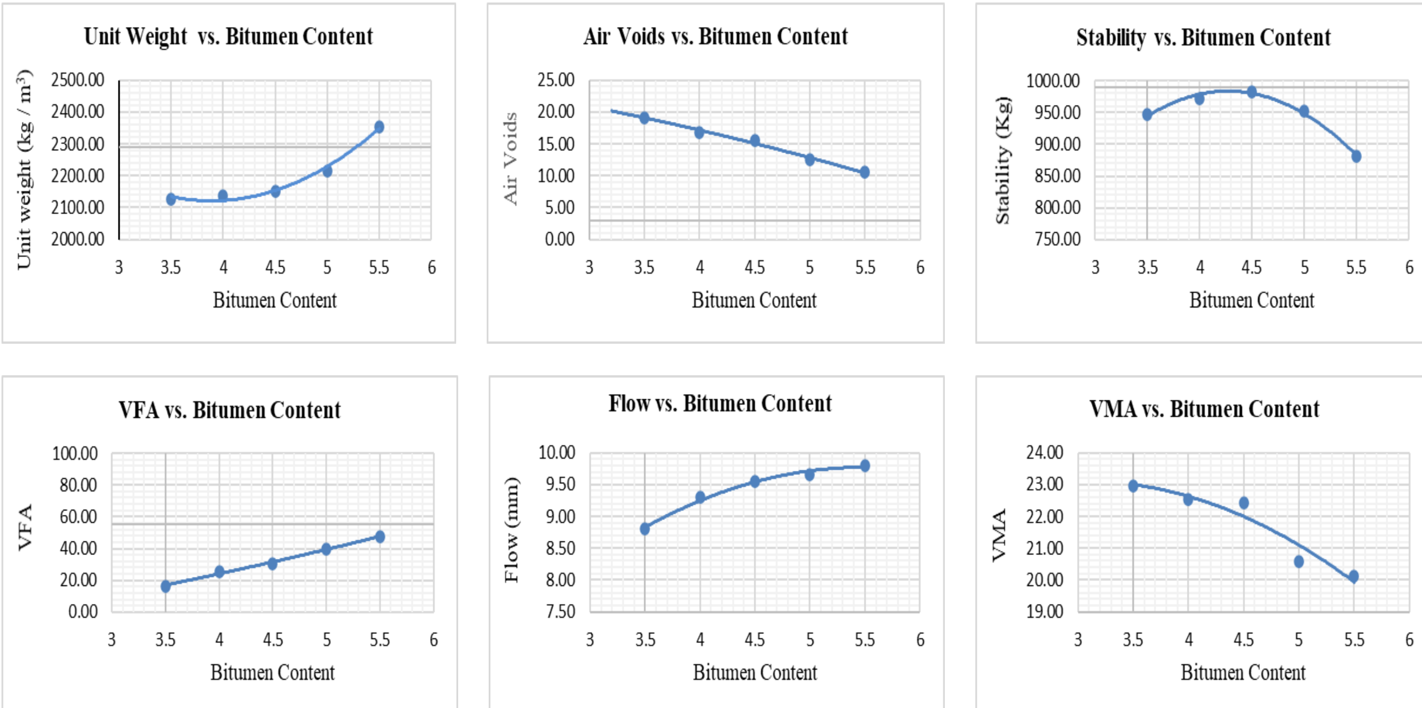


Figure 4 – Graphs for 0.5% steel modified mixture

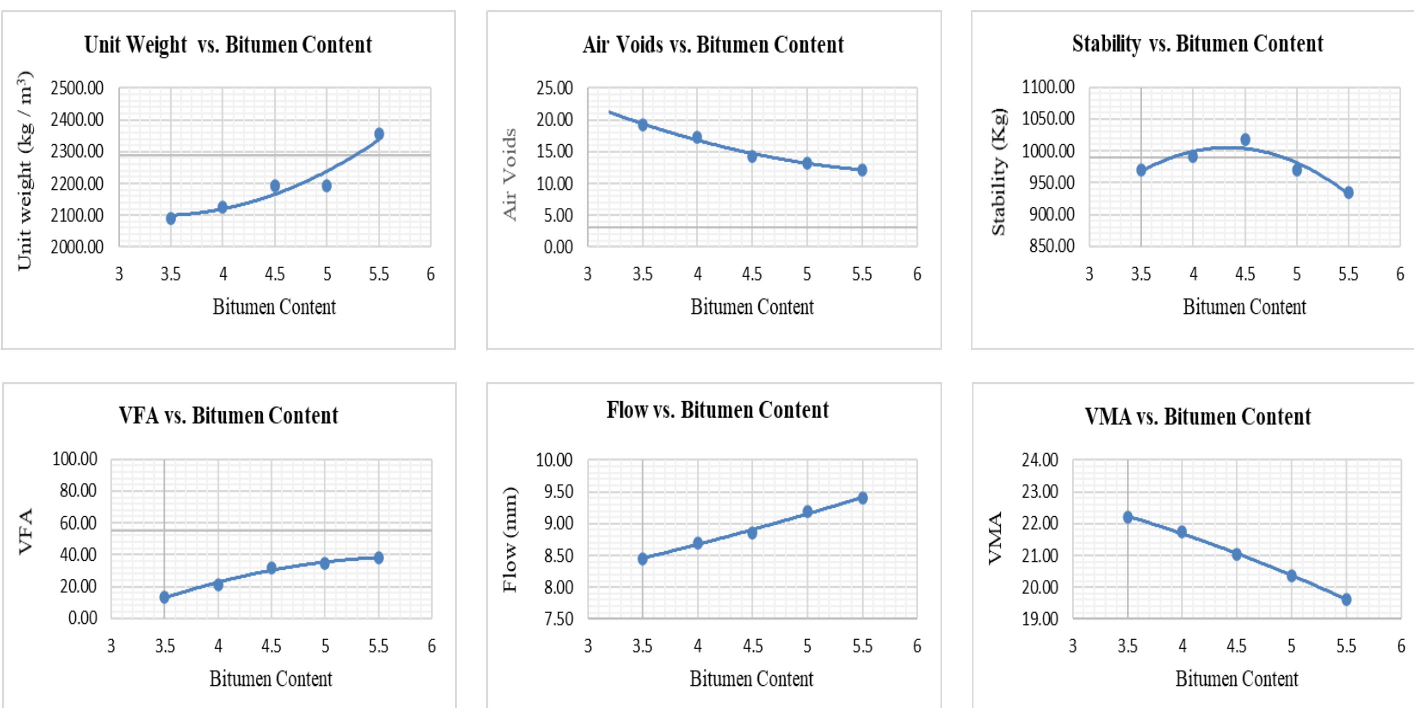
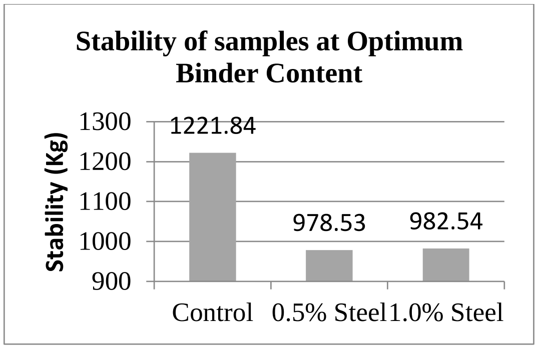


Figure 5 – Graphs for 1.0% steel modified mixture

We can see in Figure 6a that, Steel fiber modified samples have shown lowest stability at the optimum binder content. It is evident from the Figure 6b that, at optimum asphalt content, flow values in steel modified samples are comparatively highest. Also, mix-design criteria at optimum binder content is not satisfied for steel-modified samples.



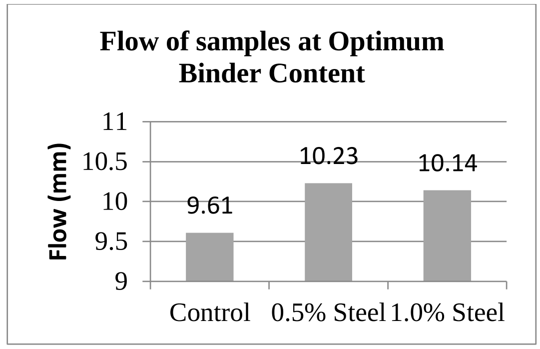


Figure 6 – a. Stability of the control & modified samples at OBC. b. Flow of the control & modified samples at OBC

5 CONCLUSION

In this study, steel fibers were used as modification in asphalt concrete. Main purpose of this research was to study the effect of the fiber addition using dry method in the asphalt mixture and the performance of hot mix asphalt. 0.5% and 1.0% by weight steel fiber was added to asphalt mixture for the analysis. It is concluded from the results that steel modified asphalt mixtures did not show good performance as the stability decreases up to 20%. Possible reason for this was the incompatibility of the steel fiber with the asphalt mixture as adequate bonding could not take place, due to which stability values of such mixture were found to be less than control samples. However, steel fiber is good for increasing electrical conductivity of the pavement and applications related to it are prodigiously revolutionary.

ACKNOWLEDGMENT

The authors would like to thank Muhammad Asad Hayat and Muhammad Farhan Ahsan who helped thorough out the experimental work, particularly TITE department, UET Taxila for providing laboratory assistance.

REFERENCES

[1] A. Qadir, "Rutting performance of polypropylene modified asphalt concrete," International Journal of Civil Engineering, vol. 12, pp. 304-312, 2014.
[2] S. Tapkın, Ü. Uşar, A. Tuncan, and M. Tuncan, "Repeated creep behavior of polypropylene fiber-reinforced bituminous mixtures," *Journal of Transportation Engineering,* vol. 135, pp. 240-249, 2009.
[3] Y. R. Kim, *Modeling of asphalt concrete*, 2008.
[4] S. Serin, N. Morova, M. Saltan, and S. Terzi, "Investigation of usability of steel fibers in asphalt concrete mixtures," *Construction and Building Materials,* vol. 36, pp. 238-244, 2012.
[5] A. García, J. Norambuena-Contreras, M. N. Partl, and P. Schuetz, "Uniformity and mechanical properties of dense asphalt concrete with steel wool fibers," *Construction and building materials*, vol. 43, pp. 107-117, 2013.
[6] H. Wang, J. Yang, H. Liao, and X. Chen, "Electrical and mechanical properties of asphalt concrete containing conductive fibers and fillers," *Construction and Building Materials,* vol. 122, pp. 184-190, 2016.
[7] Y. Paluri, S. Mogili, H. Mudavath, and R. K. Pancharathi, "A study on the influence of steel fibers on the performance of Fine Reclaimed Asphalt Pavement (FRAP) in pavement quality concrete," *Materials Today: Proceedings*, 2020.
[8] J. F. Guo, "The Effect of Steel Fiber on the Road Performence of Asphalt Concrete," in *Applied mechanics and materials*, 2014, pp. 1342-1345.
[9] S. Wu, P. Pan, M. Chen, and Y. Zhang, "Analysis of characteristics of electrically conductive asphalt concrete prepared by multiplex conductive materials," *Journal of materials in civil engineering,* vol. 25, pp. 871-879, 2013.
[10] Q. Liu, E. Schlangen, and M. Van De Ven, "Induction healing of porous asphalt," *Transportation research record,* vol. 2305, pp. 95-101, 2012.
[11] A. García, M. Bueno, J. Norambuena-Contreras, and M. N. Partl, "Induction healing of dense asphalt concrete," *Construction and Building Materials,* vol. 49, pp. 1-7, 2013.
[12] A. Menozzi, A. Garcia, M. N. Partl, G. Tebaldi, and P. Schuetz, "Induction healing of fatigue damage in asphalt test samples," *Construction and Building Materials,* vol. 74, pp. 162-168, 2015.
[13] R. B. Mallick, B.-L. Chen, S. Bhowmick, and M. Hulen, "Capturing solar energy from asphalt pavements," in *International symposium on asphalt pavements and environment, international society for asphalt pavements, Zurich, Switzerland*, 2008, pp. 161-172.

[14] S. Esfandiarpour, "Hybrid Reinforcement of Asphalt-Concrete Mixtures Using Glass and Polypropylene Fibers," Eastern Mediterranean University (EMU), 2010.

INFLUENCE OF MORINGA OIL ON ADHESION AND MOISTURE SUSCEPTIBILITY OF RECLAIMED ASPHALT PAVEMENT

[a] Muhammad Akhtar, [b] Jawad Hussain, [c] Muhammad Sohail Jameel
a: Department of Civil Engineering, University of Engineering and Technology Taxila, Pakistan, akhtarm184@yahoo.com
b: Department of Civil Engineering, University of Engineering and Technology Taxila, Pakistan, Jawad.hussain@uettaxila.edu.pk
c: Department of Civil Engineering, University of Engineering and Technology Taxila, Pakistan, sohailjamil10@yahoo.com

Abstract- Due to high traffic loading and environmental exposure the bitumen binder becomes stiff which losses its physical and chemical properties. To use the high content of Reclaimed Asphalt Pavement (RAP) in asphalt mixture, recycling is done. Recycling of asphalt pavement not only save the money but also at the same time it protects our environment. Therefore, to recover its properties different types of rejuvenators have been used in RAP. In this study Moringa Oleifera (MO) lam seeds oil (0%, 3%, 6% and 9% by weight of binder) is used as a rejuvenator and Bitumen bond strength (BBS) and Rolling Bottle Test (RBT) is performed. Results of Conventional testing revealed that by adding MO oil in RAP binder penetration values increases and softening point decreases respectively, as percentage increases. Results of BBS testing shows that by increasing the percentage of MO oil in RAP Pull of Tensile Strength (POTS) values are decreased and failure changes from cohesive to adhesive after wet conditioning.

Keywords- Conventional, Reclaimed Asphalt Pavement, Recycling, Adhesion

1 INTRODUCTION

Due to the oxidation and environmental exposure, flexible pavements start to destroy after a few years. About 80% of the road network consists of flexible pavements. The construction of flexible pavements is increasing vividly. As the demand for flexible pavements is increasing, the demand for aggregate and bitumen binder is also increasing. In order to control the new demand of aggregate and bitumen binder in the construction of road, the Reclaimed Asphalt Pavement (RAP) should be used. The materials which are obtained from the milling, recycling and breaking of the old pavement is called RAP. It consists of aged binder, which is stiff and hard, although RAP is good in rutting but prone to failure in fatigue cracking and moisture damage. To use the higher percentage of RAP in asphalt pavement there is need to use the recycling agent (RA) or rejuvenators in RAP to overcome the lost characteristics of bitumen binder[1].

The aged binder comprises of asphaltene and maltenes, with the passage of time due to traffic loading and environmental exposure the ratio of asphaltene to maltenes disturb and binder become stiff and aged. The maltenes content decreases due to aging but asphaltene contents increase, this proportion changes the chemical structure of bitumen binder. The ratio of asphaltene to maltenes can be recovered by using a rejuvenator or RA. The care should be taken by deciding the amount of rejuvenator because the dosage of RA plays a vital role in restoring the bitumen binder properties. To decide the amount of RA, needed to obtain a particular grade (performance grade, penetration or viscosity grade), different criteria have been used such as rheological characteristics, high-temperature viscosity, performance characteristics etc.[2]. In order to decrease the stiffness, viscosity and brittleness in rap binder the rejuvenators which are obtained from natural resources are added. In the previous study maltenes base and vegetable base oil have been added in high aged binder and results show better in improving the flow characteristics [3]. The elasticity and viscosity of the aged binder have recovered in the previous study by adding different types of organic oil rejuvenators [4]. The recycled cooking oil is good in improving low-grade temperature [5]. Since the aged binder is brittle and stiff, therefore it is necessary to understand the low temperature cracking properties of the aged binder when using RAP [6]. Time-temperature behavior and mechanical restoration can be obtained by with the determination of a dynamic shear rheometer [7]. The physical characteristics like penetration, ductility, softening, penetration index, viscosity, and penetration ratio of aged binder can be improved by its level of virgin binder at the optimum dosage of waste edible vegetable oil different for different bitumen binder [8].

Although the stiffness and brittleness properties of RAP binder can be used to avoid permanent deformation at the same time it loses physical properties and water penetrates into the cracks and moisture susceptibility increases due to cracking. Therefore, to overcome this issue MO oil is used as a rejuvenator to recover its lost physical characteristics and decreases the moisture susceptibility to the virgin binder level that 100% RAP can be used in the flexible pavement and it can save the money and also protect the environment.

1.1 Research significance

The RAP material, which is obtained from milling, ripping and breaking of roads comprises of aged binder. It cannot be used to 100% in the new construction road without adding rejuvenators because it loses the physical properties and moisture susceptibility is also compromised and it also causes environmental pollution because of emission of carbon compounds. There is need of recycling to reduce the use of natural resources and use renewable source. MO oil is used as rejuvenator to recover the properties (physical and moisture damage resistance) which has been lost during aging. It is renewable and green additive which can protect our environment and can save the cost by using with RAP binder

2 EXPERIMENTAL AND RESEARCH METHODOLOGY

Aggregate from Margalla crush and MO Oil as a rejuvenator is used. MO oil is a renewable and biodegradable source that is found in the Punjab region of Pakistan. It is an antioxidant agent in which the oleic acid is to be found about 70% which means that it has very low unsaturated contents. The RAP material was collected from N-5 Taxila, Pakistan on the tail road which is a one-way double lane. Aged binder was extracted by using centrifuge apparatus and ottava according to ASTM D2172 and ASTM D5404 respectively. The aged bitumen binder was heated at 145 ºC for 45 minutes after that MO oil was added by varying percentages of 0%, 3 %, 6 % and 9% by weight of aged binder by glass rod giving successively heat and shake. The Chemical composition of MO oil is shown in table 1.

Table 1- The Chemical Composition of Moringa Oil

Rejuvenator Composition	Moringa Oil (%)
Palmitic acid	6.45
Oleic acid	73.22
Stearic acid	5.50
Arachidic acid	4.08
Behenic acid	6.61

The effect of moringa oil in the aged binder was characterized by performing penetration and softening point test as per ASTM D5, ASTM D36 respectively.

To investigate the bonding of bitumen with the aggregate after dry and wet condition PATTI (Pneumatic Adhesion Tensile Testing Instrument) was performed in terms of the BBS test as per ASTM D 4541. For the preparation of the sample, the bitumen binder and sandstone aggregates were heated at 145 ºC to ensure the proper bonding of stud with aggregates.

To investigate the moisture susceptibility of aged and rejuvenated binder, RBT as per BS EN 12697-11 was performed. For the preparation of sample 170g aggregate and 8g bitumen was mixed. The bitumen coating on the sample was taken after 6, 24, 48 and 72 hours of rolling time.

The flow chart of research methodology is given below in figure 1.

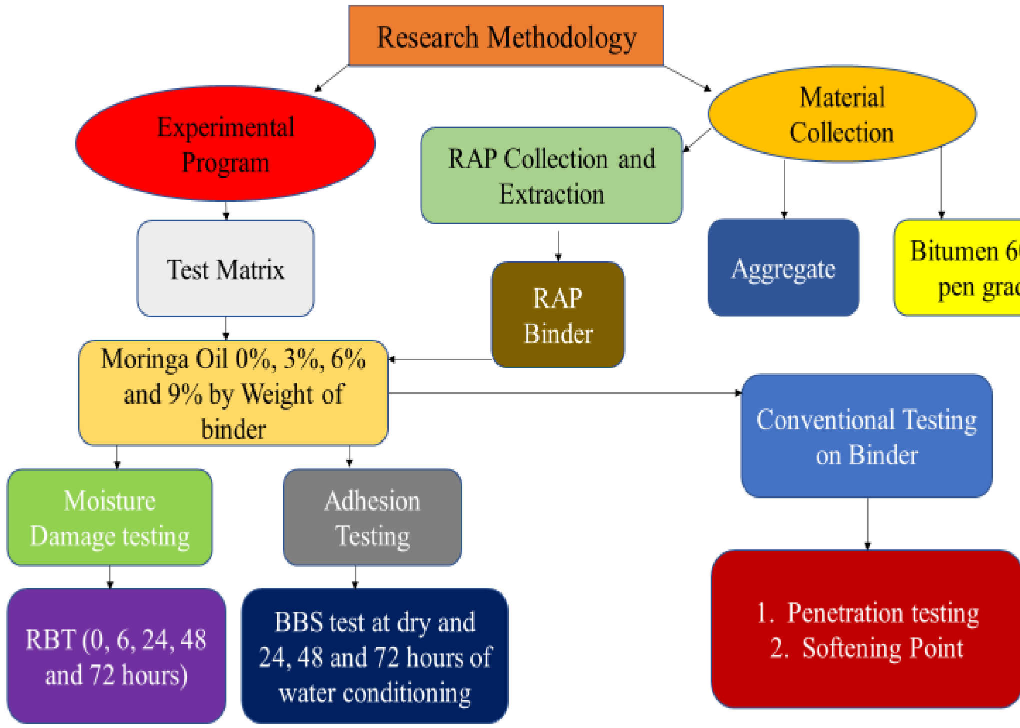


Figure 1- Research Methodology

3 RESULTS

3.1 Physical testing

To check the effect of MO oil in the RAP binder physical testing (penetration and softening point test) was performed. From figure 2 the value of penetration of RAP binder was decreased 57% of the 60-70 pen bitumen. By adding 3% by weight of binder of MO oil in the RAP binder the value of penetration was increased about 42% as compared to the 60-70 pen bitumen. By adding 6% amount of MO oil in the RAP binder the value of penetration was increased about 31%. By adding the 9% amount of MO oil in the RAP binder the value of penetration meets the 60-70 pen bitumen.

The value of the softening point of the RAP binder was increased by 38% as compared to the 60-70 pen bitumen. By adding 3% of MO oil the value of softening point decreased about 20% of the 60-70 pen bitumen. By adding 6% of MO oil in the RAP binder the value of softening point decreased about 10% of the 60-70 pen bitumen. By adding 9% of MO oil in the RAP binder the value of softening point meets the 60-70 pen bitumen.

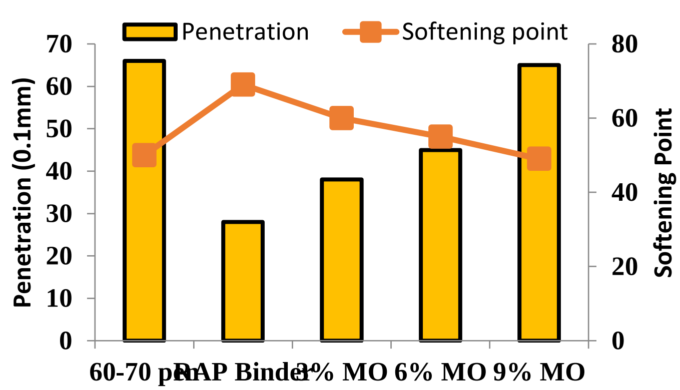


Figure 2- 60-70 pen bitumen, RAP and modified binder penetration and softening values

3.2 BBS testing

The experimental investigation of 60-70 pen bitumen, reclaimed asphalt pavement (RAP), and modified binder (0%, 3%, 6% and 9% MO oil) is done by using the Pneumatic Adhesion Tensile Testing Instrument (PATTI). All samples were tested under dry and wet conditions (0, 24, 48 and 72 hours). The 60-70 pen bitumen, RAP and modified binder were used to check the bond strength of bitumen and aggregate. The percentages of RAP binder with moringa oleifra lam seeds oil (MO oil) were checked at 0%, 3%, 6% and 9%. The burst pressure at which stud disperse from the aggregate can be found from PATTI which is then used in equation 1 to find Pull off Tensile Strength (POTS).

$$POTS = \frac{(BP \times A_g) - C}{A_{ps}} \qquad (1)$$

POTS is the pull-off tensile strength
BP is burst pressure
A_g is the contact area having a value of 2620 mm^2
C is the piston constant 0.286
A_{ps} is the area of pull-stud having a value of 127 mm^2, for this study F-4, stud type was used.

From figure 3 the value of POTS of RAP binder at dry condition increased by about 52% as compared to the 60-70 pen bitumen. By adding the 3% amount of MO oil in the RAP binder the value of POTS increased about 27%, 6% amount of MO oil added in the RAP binder to increase the value of POTS by 13% and addition of 9% amount of MO oil in the RAP binder the value of POTS meets the value of the 60-70 pen bitumen binder at dry conditioning respectively.
After 72 hours of water conditioning the POTS values of 60-70 pen bitumen, RAP and modified binder decreased as compared to dry conditions. It is because the water penetrates the interface between bitumen and aggregate which weakens the bond thus POTS values decrease [9]. The error bar in the figure-3 shows the positive mean deviation values from the 60-70 pen bitumen.

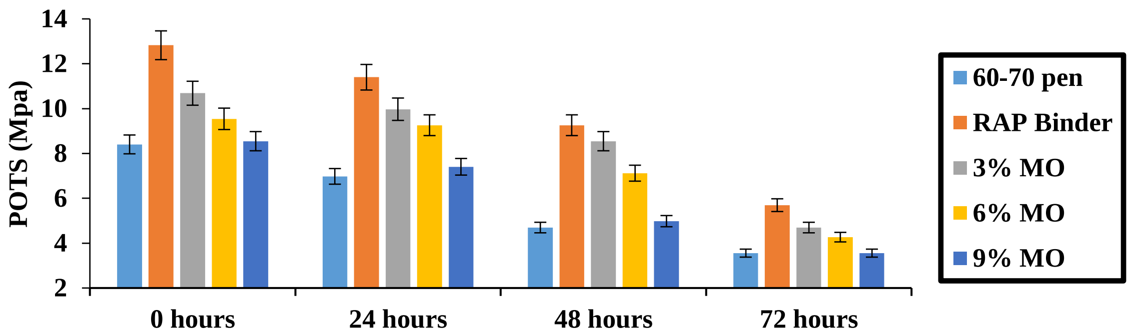


Figure 3- POTS values of RAP, 60-70 pen bitumen, and MO modified binder after dry and wet conditioning.

4 FAILURE PATTERN ANALYSIS

At dry conditioning, bitumen makes a strong bond with aggregate. When stud displaces the aggregate the remaining bitumen on aggregate confirms the type of failure. When bitumen remains on aggregate is more than 50% then failure is cohesive if it is less than 50% then it is adhesive. At dry condition, more bitumen remains on the aggregate surface which means failure is cohesive. After water conditioning, water penetrates the bitumen-aggregate interface which deteriorates the bond thus adhesive failure takes place.

Table 1- RAP, Virgin, and MO modified binder bitumen coverage and failure type.

CT*	60-70 pen	RAP Binder	3% MO	6% MO	9% MO
0 hours	60C/A	75C	55C	80C	60C
24 hours	45A	60C	50C/A	60C	50C/A
48 hours	35A	40A	30A	25A	35A
72 hours	25A	30A	25A	20A	30A

CT* curing time; A, adhesive failure; C, cohesive failure; C/A, 50% adhesive 50% cohesive failure

From the above table, failure type changes from cohesive to cohesive-adhesive then adhesive failure at 24 hours of water conditioning at 9% MO modified binder. At RAP binder failure change to cohesive to adhesive after 24 hours of wet conditioning.

4.1 Rolling Bottle Test

The RBT is performed to check the moisture susceptibility of 60-70 pen bitumen, RAP and modified binder.

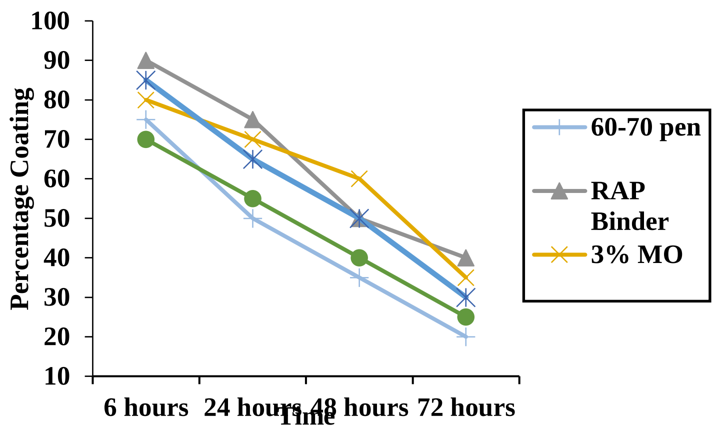


Figure 4-Comparison of bitumen coverage between 60/70 pen, RAP and modified binder at different duration.

From figure 4, it can be seen that with the increase in rolling time the affinity of bitumen decreases. At 72 hours of rolling time RAP binder shows 20% more bitumen coverage as compared to the 60-70 pen bitumen. By adding 3% and 6% amount of MO oil in the RAP binder shows 15 % and 10% more bitumen coverage as compared to the 60-70 pen bitumen respectively. While adding 9% amount of MO oil in the RAP binder shows similar results as compared to 60-70 pen bitumen.

5 PRACTICAL IMPLEMENTATION OF RESEARCH WORK IN INDUSTRY

The RAP material, which is obtained from milling, ripping and breaking of roads comprises of aged binder. While using MO oil in the RAP binder maximum RAP content can be used in the industry which give the similar results to virgin binder. If the production of MO oil is increased in Pakistan at large scale which can be proven cost effective and environmental friendly rejuvenator for the RAP binder. The aged binder has been used in the industry maximum up to 60%.

6 CONCLUSION

Following conclusions can be drawn from the conducted study:

- With the addition of 3% and 6% MO oil in the RAP binder, the penetration value increases 42% and 31%, thus the softening point decreases 20% and 10% respectively as compared to the 60-70 pen bitumen. While with the addition of 9% MO oil in the RAP binder gives the similar result of 60/70 pen bitumen.
- RAP binder shows 52% higher POTS values as compared to the 60-70 pen bitumen. The addition of 3% and 6% MO oil in the RAP binder POTS values increases by 27% and 13% respectively as compared to 60-70 pen bitumen. After 72 hours of water conditioning the POTS values of 60-70 pen bitumen, RAP and modified binder decreased as compared to dry condition.
- At 72 hours of rolling time RAP binder shows 20% more bitumen coverage as compared to the 60-70 pen bitumen binder. By adding the amount of 3% and 6% MO oil in the RAP binder shows 15 % and 10% more bitumen

coverage as compared to the 60-70 pen bitumen respectively. While addition of 9% of MO oil in the RAP binder shows similar results as compared to 60-70 pen bitumen.

REFERENCES

[1] S. K. Pradhan and U. C. Sahoo, "Performance assessment of aged binder rejuvenated with Polanga oil," J. Traffic Transp. Eng. (English Ed., vol. 6, no. 6, pp. 608–620, 2019.
[2] R. Romera *et al.*, "Rheological aspects of the rejuvenation of aged bitumen," *Rheol. acta*, vol. 45, no. 4, pp. 474–478, 2006.
[3] X. Yu, M. Zaumanis, S. Dos Santos, and L. D. Poulikakos, "Rheological, microscopic, and chemical characterization of the rejuvenating effect on asphalt binders," *Fuel*, vol. 135, pp. 162–171, 2014.
[4] X. Cao, H. Wang, X. Cao, W. Sun, H. Zhu, and B. Tang, "Investigation of rheological and chemical properties asphalt binder rejuvenated with waste vegetable oil," *Constr. Build. Mater.*, vol. 180, pp. 455–463, 2018.
[5] H. Asli, E. Ahmadinia, M. Zargar, and M. R. Karim, "Investigation on physical properties of waste cooking oil–Rejuvenated bitumen binder," *Constr. Build. Mater.*, vol. 37, pp. 398–405, 2012.
[6] D. Singh and S. Girimath, "Influence of RAP sources and proportions on fracture and low temperature cracking performance of polymer modified binder," *Constr. Build. Mater.*, vol. 120, pp. 10–18, 2016.
[7] M. C. Cavalli, M. Zaumanis, E. Mazza, M. N. Partl, and L. D. Poulikakos, "Aging effect on rheology and cracking behaviour of reclaimed binder with bio-based rejuvenators," *J. Clean. Prod.*, vol. 189, pp. 88–97, 2018.
[8] M. Chen, B. Leng, S. Wu, and Y. Sang, "Physical, chemical and rheological properties of waste edible vegetable oil rejuvenated asphalt binders," *Constr. Build. Mater.*, vol. 66, pp. 286–298, 2014.
[9] S. A. Asif, N. Ahmed, A. Hayat, S. Hussan, F. Shabbir, and K. Mehmood, "Study of adhesion characteristics of different bitumen–aggregate combinations using bitumen bond strength test," *J. Chinese Inst. Eng. Trans. Chinese Inst. Eng. A/Chung-kuo K. Ch'eng Hsuch K'an*, vol. 41, no. 5, pp. 430–440, 2018.

EFFECT OF TRANSPORT INFRASTRUCTURE DEVELOPMENT ON HEALTH OF NATIVES: A CASE STUDY OF LAHORE ORANGE LINE METRO TRAIN PROJECT

Zeeshan Ullah[a]*, Engr. Shah Jahan[b], Engr. Sami Ullah[c], Engr. Muhammad Irfan[d], Engr. Tallat Habib[e]
a: PhD student, Dept. of Construction Engineering & Management (CE&M), NUST, Islamabad, zeshan880@gmail.com
b: Assistant Professor, University of Lahore, Gujarat Campus, Shahjahan1002@gmail.com
c: Assistant Director, TEPA, LDA, samigondal.lda@gmail.com
d: Lab Engineer, Civil Engineering Department, KFUEIT Rahim Yar khan, engr.mirfan1992@gmail.com
e: SDO DG Khan, Irrigation Department, Punjab, talathqureshi@gmail.com

Abstract: Development of Transport infrastructure is an essential necessity for evolution of economic growth and continuing improvement in living standards of citified occupants. However, it causes environmental contamination also lead by several factors. Construction activities yield inorganic dust, noise, vibrations, and volatile organic compounds. Natives along the urban project sites are exposed frequently to multiple health hazards including immunological, neurological, hematological, and respiratory diseases. Implementation of environment management plan (EMP) is considered mandatory for infrastructure projects and is followed by all stake holders in developed countries but there are so many challenges in developing countries like Pakistan. Environmental impact assessment (EIA) is obligatory part of the construction projects according to Pakistan Environmental Protection Act (PEPA), 1997. But unfortunately, EPM is not implemented and followed in its true sense. This research is comprised of Effects of Lahore Orange Line Metro Train project to the health of natives along the project sites regarding construction phase of project. 142 respondents are selected randomly along corridor i.e. from stabling yard to Depot. Data collected through questionnaire survey and analyzed by descriptive analysis using statistical tools. Specific sensory nervous system i.e. Sight (vision), Hearing (audition), Taste (gustation), Smell (olfaction), Touch (somatosensorial), skin (dermatological) and respirational effects are the special areas of research. Distress due to obtrusion of utility lines and general living of natives of project have also been investigated. The study framed guide lines to identify the health hazards for natives of project and concluded logical severity level against each hazard. This will be helpful to adopt realistic approach to distinguish the concerning nuisances individually in connection with remedial measures for future projects to enhance sustainable urban infrastructure development trends in developing countries like Pakistan.

Keywords: Bus Rapid Transit System, Environment Management Plan, Lahore Orange Line Metro Train, Health Effects.

1 INTRODUCTION

Infrastructure development is the essence of modernized civilization to meet prime necessities of community. It plays vital role to upgrade wellbeing of society and boost economy as well. Concurrently, environmental deterioration caused by infrastructure construction is utmost argued discipline regionally and globally. Construction is one of the major origins of environmental pollution. Effectual arrangements for environment friendly infrastructure are an explanatory public policy issue internationally [1]. Development of a large project take account of multidimensional courses which involve several tasks and activities. Massive engineering machines, equipment, concrete batching plants, asphalt plants, heavy vehicles for transportation of construction materials are the primary needs. Execution of activities comprised of excavation, Earth works, backfilling/sand filling, brick works, drilling, fixation of scaffolding, welding, drainage structures and concreting etc. are compulsory elements. All these factors contribute to pollute the environment somehow or the other.

Construction machines and plants are originators of toxic gases and emissions. Ponding of water for drilling of reverse rotary piles put its share to contaminate the surrounding and cause various health hazards. Air pollution due to dust, smoke or composite originate consequential health concerns to humans. Pollution due to noise and vibrations cause annoyance, sleep distress and generate reasons for day time sleep. In conjunction with construction teams at work sites, natives are sufferer exposed to such polluted environment and have to face numerous health issues if pollutants not addressed accordingly [2].

Environmental protection is a dominant issue all around the world. Researchers define human health impacts as inclusive of not only specific health problems but also the consideration of general well-being. It implicates illness, injury, psychosocial belongings such as community severance and disturbance. 190 members of United Nations out of 193 have legislated the systematic process of EIA for development projects notwithstanding the considerations to comprehensive health impacts within EIAs endured impoverished [3]. World Health Organization (WHO) articulated serious concerns that healthy transportation policy has not been fully acknowledged seriously. EIA system was initially established as National Environmental Policy Act (NEPA) in US and instantly the procedure of EIA has been accompanied by more than 100 countries. Aspects of social costs including health impacts related to construction projects have been recognized and regulated in developed countries but unfortunately there is meagre research in this domain in developing countries [4]. Health impact assessment practices in UK are actively dominant by Merseyside model [2]. Unfortunately, in Asia the situation is frightening where two thirds of the cities are failing to meet the air quality standards of European Union i.e. 40μg/m3 of PM10. 34 ponderous polluted cities of the world among 57 with 100μg/m3 level of PM10 are Asian [5]. Construction of mass rapid transit system in large cities of Pakistan have been started since last few years. It is very important to understand that such projects in urbanized areas cause several health issues for natives' community. In feasibility study of the project it was recommended that priority timings of construction will be evening and night but construction works were proceeded round the clock to complete the project within due time. Being Fast Track Project, construction activities were executed simultaneously with full swing generating more originators of environmental pollution. So, natives of the project were exposed to health hazardous frequently [3].

Pakistan environmental protection authority and provincial EPAs are the responsible for surveillance of air quality pollution. Prior to start the inception of any project, EPA, under section 12 of PEPA 2012, publish a notice in local newspapers to assess if community has concerns about construction of proposed project (EPD, GOP). However, it is unfortune that government of Punjab did not take into consideration the precondition fulfilment of admissible legislation to reduce the acerbity of negative effects of environment caused by development works.

2 LITERATURE REVIEW

Lahore is the capital city of Punjab Province. It's the 2nd largest populated metropolitan city of Pakistan and 16th of the world. According to 6th population census conducted in 2017, population of Lahore has exceeded to 11.126 Million (PBS Govt. of Pakistan) with density 6279 person/square kilo meter. Lahore is among top twenty most polluted cities in the world. Brisk increase in population, upsurge vehicle ownership and growing trends of urbanization have intensified traffic congestion in Lahore. Moreover, this sizable city is expanding at the rate of 4% per annum. Being the capital city of most populated province, people from other districts have to travel for their employment, social, health, educational and other necessities. Keeping in view the situation, it was need of the time to develop a sustainable urban transport system to cope the requirements. To mitigate the extensive congestion of on-road vehicles, rapid mass transit system is significant solution. The Orange Line Mass Rapid Transit (MRT) is the 1st project among network of four lines of Mass Rapid Transit. The other proposed three lines are Green Line, Blue Line and Purple Line (PMA Govt. of Punjab). Feasibility study of Lahore orange line project was done in 2007 by MVA Asia Ltd (Consultant) and updated in 2014 through addendum to feasibility by NESPAK (Renowned consultant firm in Pakistan) on direction of Punjab Mass transit Authority Lahore (PMA, Govt. of Punjab) [6].

More than two million demises are estimated globally because of direct effect of air pollution damaging to lungs and respiratory system. Among particular factors related to health concerns due to dust emission of infrastructure development projects, smog is esteemed one. The word smog attribute to the blend of pollutants and environmental factors like fog. Smog exposure leads to numerous health issues like respiratory diseases, labored breathing, eyes hypersensitivity, irritability in nose and throat etc. On 3rd of December, 2018 Lahore ranked at number 1, worst air quality in the world. Receptiveness, lucidity and liability is rapidly being encouraged by individuals, groups, organizations and governments around the globe to improve the human health by outcomes of public infrastructure construction. The significance of health impact assessment has been recognized and being implemented in developed and developing countries. Guidelines captioning several facets of environmental impact assessment have been formulated and strengthened extensively [7].

In Pakistan environmental protection assessments were initiated as Environmental Protection Ordinance 1983 and intensified as Environmental Protection Act Pakistan 1997 then reformed and was operative as Environmental Protection Assessment Regulations-2000. Pakistan environmental protection authority and provincial EPAs are the responsible for surveillance of air quality pollution. Prior to start the inception of any project, EPA, under section 12 of PEPA 2012, publish a notice in local newspapers to assess if community has concerns about construction of proposed project (EPD, GOP). However, it is unfortune that government of Punjab did not take into consideration the precondition fulfilment of admissible legislation to reduce the acerbity of negative effects of environment caused by development works. Unfortunately, health considerations regarding health concerns of natives of projects are disregarded brutally. Untoward condition is that these natives even have no concept of their principal deserving. Studies have proven that residents of these projects are entangled by considerable health issues like coughing, dust vulnerability, sneeze issues, asthma, skin problems and others [8].

2.1 Impact Of Construction Industry On Communal Health

Among different industries the construction industry is the most dangerous industry. In accordance to the EU-OSHA, "The deteriorating health and mortality rate due to the construction industry is greater than that of any other industry." Construction and site activities are primarily responsible different types of diseases such as hypertension (HBP), hypertension (cardiovascular disease, pneumonia, breathing diseases, cough, asthma, cardiovascular disease, stroke, premature death and type 2 diabetes [9]. These are the main diseases. contaminated by construction contaminants. In the estimation global pollution that can be attributed to buildings and polluted air quality in construction activities is affected the city is 23% responsible for climate change through gas 50%, drinking water pollution by 40%, landfill pollution through construction activities occur 50% ozone depletion pollution by pollution is 50% [10].

3 RESEARCH METHODOLOGY

The research is considered as logical when cessation is accurate, research design is visionary representation and not beyond the area within which research is carried out. It comprised of an action plan established to framework collection, determine and analyze data. Considering the factors that are being utilized in scientific research and learning the way forward to conduct research, make findings for which statistics is to applied and analyze statistical results are the objectives of researchers in current scientific based era. In research designing, it is considered mandatory to concede the sort of evidence to response the research question in logical way. Owing to investigate the effects of transport infrastructure development on health of natives of Lahore orange line metro train project four main phases were categorized i.e. Fundamental study, Collection of data, Analysis of collected data and write up of the study.

3.1 Sampling Procedure

Surveys are very conventional techniques to organize the research. These are considered as systemized tool to extract explicit information. Interview technique is extensively being used for knowledge building purpose in human sciences. Face to face interviews with closed ended questions are done by random survey technique to collect primary data from respondents living along both sides of corridor of Lahore orange line metro train project Lahore. Two numbers volunteers were deployed after due training for this purpose. Samples were collected from Stabling yard (Start of the project) to Depot (End of the project) [11]. The data is shown in table-1:

Table 40: Detail of sampling

Sr. No	Data collected along both sides of corridor		No. of samples collected	
	Initial Point	**Final Point**	**Left Side**	**Right Side**
1	Stabling Yard (Start of Project)	Pakistan Mint Station	9	13
2	Pakistan Mint Station	Railway Station	15	13
3	Railway Station	Gulshan Ravi Station	9	13

4	Gulshan Ravi Station	Sabzazar Station	14	13
5	Sabzazar Station	Thoker Niaz Baig Station	15	15
6	Thoker Niaz Baig Station	Depot (End of project)	7	6
Total Collected Sample			**69+73=142**	

For assessment of health effects caused by development projects, participation of community is considered as convenient and befitting procedure**.** Population for sampling was 142 respondents/ natives of Lahore orange line metro train project. The route of project passes through most congested areas of Lahore city. On both sides of corridor there are shops, fuel pumps, workshops, food points etc. Commercial activities are running day and night in these areas. 125 respondents out of 142 were from the same community. Seventeen respondents were permanent residents of project periphery.

4 RESULTS AND DISCUSSIONS

Transportation is one area where change is possible and provides a good example of the opportunities for positive synergies between the environment and health. This sector is one of the fastest growing greenhouse emitters in many countries, including Pakistan and transportation infrastructure affect health in many ways. A key challenge in the future is to meet the basic health and wellbeing needs of the large section of populations in developing countries that are currently living in 'energy poverty' while protecting the environment and human health. This chapter describes the results obtained from questionnaire analysis of the effect of Orange Line Metro Train Project on health of people in locality. Following the detail of respondent's characteristics and criticality indices of health factors.

4.1 Criticality Index Of Health Factors

Criticality index for 19 variables of all 3 sections have been determined. Criticality index for each variable was calculated. Criticality Index is extensively used by researchers due to its reliable & effectual results specifically in ranking the variables. It has also been utilized to itemize the relative significance of common problems and concerns of stakeholders in construction industry. Importance index was used to assess the factors affecting efficiency of workers in construction industry. Criticality Index has also been practiced in ranking the dominant challenges to the functioning of program management auspiciously in construction field. Criticality Index of 19 variables have been determined by using the following formula.

$$\mathbf{C.I = \sum i=1\ W_i X_i}$$

Where C.I is the Criticality Index, i expresses the response by respondent i.e. No effect, Mild, Medium, High & Very High in terms of 0, 1, 2, 3 & 4, W_i is the weight allocated to i^{th} response, X_i is the frequency of i_{th} response given as percentage of total responses. The values of Criticality Indices lie between 0 and 1. More tendency of C.I values towards 1 represents the more criticality of variables. Any variable with value greater than 0.5 will be considered as 'More Critical'. Cronbach's alpha values to evaluate the reliability and correlation of significant variables have been calculated. Cronbach's alpha is considered as extensive measure for reliability of data. It is one of utmost frequently used method to evaluate the internal consistency of data. Mean values and Standard deviations have also been computed

The data collected to perceive the effects of Orange line metro train on health of people living in its locality is ordinal data which is best possibly can be viewed in the form of indices of each health factor to determine which one is more critical. The criticality index of each factor has been calculated and results are shown in Figure-1. It represents that out of total 19 selected health factors, 13 are more critical as their C.I are greater than 0.5, three factors are considered critical provided their C.I is greater than 0.4. three factors have CI equal to zero or less than 0.3 and hence these are considered non-critical.

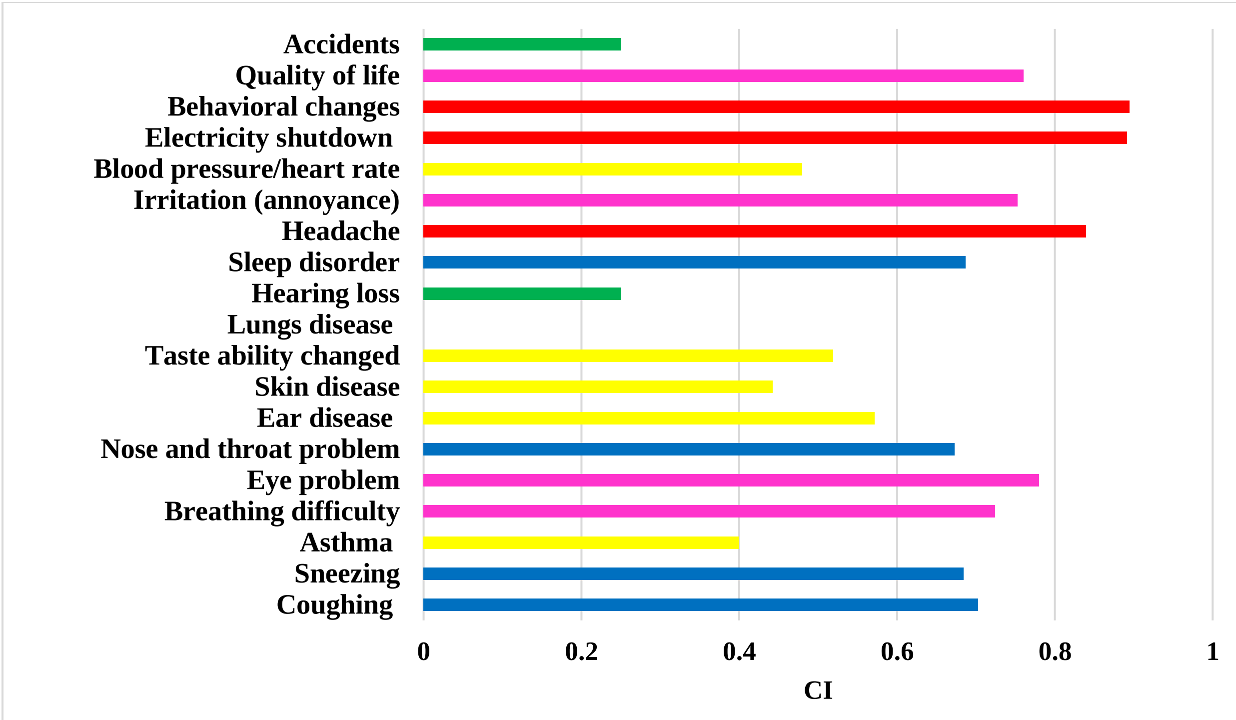


Figure.1: Criticality index of Health factors

4.2 *Analysis Based On Age And Distance Of Respondents*

The data was categorized based on the age and distance of respondents. Four age groups were selected which are 19-25year, 26-35year, 36-45year and 46-55year. Their response was segregated and C.I was calculated for these groups separately to determine whether the ae of respondents has any impact on the response. Similarly, it has also been questioned from the respondents that how far away they live from orange line metro train and response range was from 5km to 80km where the number of people who lived more than 30km away from train were grouped as >30km. hence it gives five groups as 5-10km, 11-15km, 16-20km, 25-30km and >30km. Based on these groups, C.I of health factors was calculated to determine the role of distance in criticality of responses.

4.3 *Descriptive Statistics*

The following table 2 and 3 represents descriptive statistics of data grouped by location or remoteness of respondents and age groups of respondents. It includes Mean, Standard Error, Median, Mode, Standard Deviation, Sample Variance, Kurtosis, Skewness and Range of response.

Table 41: Descriptive statistics of C.I value varied by remoteness of respondents

Criticality Index by Distance of	**Mean**	**Standard Error**	**Median**	**Mode**	**Standard Deviation**	**Sample Variance**	**Kurtosis**	**Skewness**	**Range**	**Minimum**	**Maximum**	**Sum**	**Count**	**Confidence Level (95.0%)**
5-10km	0.6	0.06	0.71	0.25	0.25	0.06	0.23	-0.92	0.91	0	0.91	11.47	19	0.12
11-15km	0.6	0.06	0.67	0.25	0.24	0.06	0.43	-0.93	0.89	0	0.89	11.39	19	0.12

16-20km	0.58	0.06	0.66	0.25	0.27	0.07	-0.65	-0.57	0.92	0	0.92	11.06	19	0.13
25-30km	0.59	0.06	0.68	0.5	0.27	0.07	0.87	-1.2	0.89	0	0.89	11.28	19	0.13
>30km	0.35	0.07	0.31	0	0.31	0.1	-1.37	0.23	0.84	0	0.84	6.25	18	0.15

Table 42: Descriptive statistics of C.I value by different age groups of respondents

Criticality Index by Age of	**Mean**	**Standard Error**	**Median**	**Mode**	**Standard Deviation**	**Sample Variance**	**Kurtosis**	**Skewness**	**Range**	**Minimum**	**Maximum**	**Sum**	**Count**	**Confidence Level (95.0%)**
19-25yr	0.59	0.06	0.68	0.25	0.28	0.08	0.28	-1.04	0.93	0	0.93	11.23	19	0.14
26-35yr	0.56	0.06	0.64	0.25	0.28	0.08	-0.13	-0.83	0.89	0	0.89	10.68	19	0.13
36-45yr	0.61	0.06	0.71	0.45	0.25	0.06	0.34	-0.98	0.9	0	0.9	11.5	19	0.12
46-55yr	0.61	0.07	0.77	0.25	0.3	0.09	-0.15	-0.99	0.93	0	0.93	11.54	19	0.14

It is obvious from the results that values of standard deviation are less which shows data is closer to mean values. Here it is not clear either these groups have significance difference in their responses or not.

4.4 Resourcefulness Of Response By Age And Distance

The CI of health factors were distinguished based on the age groups of respondents and the distance from train at which they reside. Figure 2 shows a correlation analysis performed on health factors. It represents that as the distance increases, the health factors appear less critical for respondents but age has no impact on it.

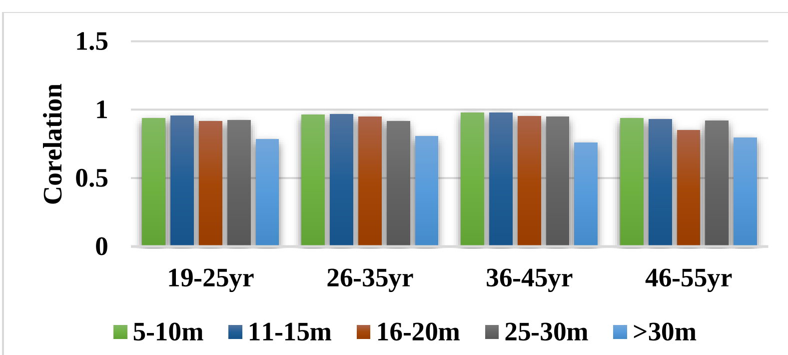


Figure.2: Correlation of Health factors by age and distance of respondents

5 CONCLUSIONS AND RECOMMENDATIONS

Construction of infrastructures are important for the development of any country. But during the construction of these infrastructures will also damage the environment and health of community of those area. After grouping data analysis was carried out by using useful statistical analysis tests like ANNOVA and t-tests. After that conclusions and recommendations were made and discussed below.

1. During the construction of road infrastructures, dust and dirt particles sustained in air causing breath problems.
2. The lungs disease, hearing loss and accidents were caused by dust particles in air but these diseases also non-critical health factors based on this research.
3. In the light of statistical analysis, it is clear that age of respondents has no effect on response and criticality index as criticality index of respondents of all age groups remains the same based on covariance and ANOVA statistics whereas it varies for distance of respondents.
4. Un-seasonal smog will be caused in the area where infrastructures are constructed which increase the accident and death rates.
5. Based on results obtained by t-Test, the people who live more than 30km away from metro train stated these health factors less critical and their responses are significantly different from that of closely resided people.
6. Cough, throat and sneeze problems were critical during the construction of road infrastructures. Acid rains were caused by the population in environment during construction of infrastructures.
7. Asthma, skin disorder blood pressure was caused by environmental damages and production of lots of noises. But these effects were less critical as critical index of these diseases was very less.
8. During construction of road infrastructures lots of noise produced that caused sleeping disorder, headache, irritation and also behavior of human being changed with this noise. Asthma, skin disorder blood pressure was caused by environmental damages and production of lots of noises. But these effects were less critical as critical index of these diseases was very less.

Infrastructures are the key construction components that define the progress of any country and also improve the economy and growth of the country. Following are the recommendations of this study:

1. The negative impacts of infrastructures can be controlled or reduced by using a proactive approach that preserves natural corridors will help with long-term sustainability of the transport infrastructure and the environment to protect.
2. Timely medical tests of surrounding community should be conducted to investigate any physical problem caused by construction process of that structure. Periodic medical treatment should be carried out for the people living in the locality of construction project.
3. Successful and sustainable projects require collaboration between governments, policy makers, infrastructure planners, environmentalist, and the community.
4. In order to control the suspension of dust and dirt particles in surrounding air, timely showering should be done during the entire period of construction of infrastructures.
5. Concrete batching plants and other machinery should be installed far away from community to the diseases produced by noise.

6. The construction of any type of infrastructure should be properly planned as a fast track project and execute it by using extra resources like machinery and man power.
7. Future research can be carried out by considering domestic people in the sample as there would be wide range of people would be there including students and job holders who spend partial time near project site and remaining time in offices or school.

REFERENCES

[1] R. Chen, B. Hu, Y. Liu, J. Xu, G. Yang, D. Xu*, et al.*, "Beyond PM2.5: The role of ultrafine particles on adverse health effects of air pollution," *Biochimica et Biophysica Acta (BBA) - General Subjects,* vol. 1860, pp. 2844-2855, 2016/12/01/ 2016.
[2] J. H. Kim, D. H. Lee, Y. Joo, K. D. Zoh, G. Ko, and J.-H. Kang, "Identification of environmental determinants for spatio-temporal patterns of norovirus outbreaks in Korea using a geographic information system and binary response models," *Science of The Total Environment,* vol. 569-570, pp. 291-299, 2016/11/01/ 2016.
[3] R. Rückerl, R. Hampel, S. Breitner, J. Cyrys, U. Kraus, J. Carter*, et al.*, "Associations between ambient air pollution and blood markers of inflammation and coagulation/fibrinolysis in susceptible populations," *Environment International,* vol. 70, pp. 32-49, 2014/09/01/ 2014.
[4] F. Al-Bahar Jamal and C. Crandall Keith, "Systematic Risk Management Approach for Construction Projects," *Journal of Construction Engineering and Management,* vol. 116, pp. 533-546, 1990/09/01 1990.
[5] D. G. Karottki, G. Bekö, G. Clausen, A. M. Madsen, Z. J. Andersen, A. Massling*, et al.*, "Cardiovascular and lung function in relation to outdoor and indoor exposure to fine and ultrafine particulate matter in middle-aged subjects," *Environment International,* vol. 73, pp. 372-381, 2014/12/01/ 2014.
[6] J. M. Bryce, G. Flintsch, and R. P. Hall, "A multi criteria decision analysis technique for including environmental impacts in sustainable infrastructure management business practices," *Transportation Research Part D: Transport and Environment,* vol. 32, pp. 435-445, 2014/10/01/ 2014.
[7] Å. Jevinger and J. A. Persson, "Consignment-level allocations of carbon emissions in road freight transport," *Transportation Research Part D: Transport and Environment,* vol. 48, pp. 298-315, 2016/10/01/ 2016.
[8] T. Münzel, F. P. Schmidt, S. Steven, J. Herzog, A. Daiber, and M. Sørensen, "Environmental Noise and the Cardiovascular System," *Journal of the American College of Cardiology,* vol. 71, pp. 688-697, 2018/02/13/ 2018.
[9] A. Papapostolou, C. Karakosta, and H. Doukas, "Analysis of policy scenarios for achieving renewable energy sources targets: A fuzzy TOPSIS approach," *Energy & Environment,* vol. 28, pp. 88-109, 2017.
[10] C. Ambrey and C. Fleming, "Public Greenspace and Life Satisfaction in Urban Australia," *Urban Studies,* vol. 51, pp. 1290-1321, 2014/05/01 2013.
[11] R. Close and M. Loosemore, "Breaking down the site hoardings: attitudes and approaches to community consultation during construction," *Construction Management and Economics,* vol. 32, pp. 816-828, 2014/08/03 2014.

ASSESSMENT OF ADHESION AND MOISTURE SUSCEPTIBILITY OF WASTE PLASTIC AND CRUMB RUBBER MODIFIED BITUMEN

[a] Hafiz Ammar Zahid, [b] Syed Bilal Ahmed Zaidi, [c] Muhammad Sohail Jameel
a: Department of Civil Engineering, University of Engineering and Technology Taxila, Pakistan, ammarzahid766@gmail.com
b: Department of Civil Engineering, University of Engineering and Technology Taxila, Pakistan, bilal.zaidi@uettaxila.edu.pk
c: Department of Civil Engineering, University of Engineering and Technology Taxila, Pakistan, sohailjamil10@yahoo.com

Abstract- Inappropriate disposal of a large amount of waste material in the form of plastic and rubber tires is a serious environmental concern. The use of these waste materials in asphalt not only enhance the properties of asphalt binder but also serves an effective means form their safe disposal. In this study Polyethylene Terephthalate and Crumb Rubber have been used in various combinations to modify 60-70 pen grade bitumen. Bitumen Bond Strength test using Pneumatic Adhesion Tensile Testing Instrument and Rolling Bottle Test were performed to evaluate the adhesion and moisture susceptibility of the modified binder. The experimental results revealed that modified bitumen with 15% Polyethylene Terephthalate shows better adhesion and moisture susceptibility compared to crumb rubber modified and control binder.

Keywords- Waste Material, Asphalt, Bitumen Bond Strength, Rolling Bottle Test.

1 INTRODUCTION

Hot mix asphalt is used for flexible pavement over a long time in all over the world. By using this traditional job mix formula (Hot mix asphalt) different stress-related problems are created resulting in rutting, fatigue cracking, and moisture damage. These problems are created due to overloading, climate condition, low and high temperatures [1][2]. To overcome all the stress-related problems binder modification is the best solution [3]. Different binder modifications are used to overcome rutting, fatigue and moisture damage. Now a day's disposal of dumps is a major problem due to lack of space and destructive for the environment. As the population is increasing, solid waste increases which causes landfill space and health problems [4][5].

Esmaeil et al. studies the effect of PET as a modifier in asphalt binder. The optimum percentage of 6% PET are showed good results on properties of asphalt mixture [6]. Zhen Leng et al. explore that by using additives of waste PET gives good performance-enhancing rutting resistance 15% and fatigue resistance 60% [7]. Mansour Fakhri et al. studies the effect of deicing salt contains Calcium Chloride, Sodium Chloride and Magnesium Chloride on moisture susceptibility. Recycled Crumb Rubber (RCR) of 0%,1%,3% and 5% are used. Moisture susceptibility (Texas Boiling Water, Pull-off Adhesion Test, and Indirect Tensile Test) are used for explaining asphalt specimens. The calcium chloride showed less adverse outcomes as compared to other deicing solution and RCR [8]. Gibreil et al. studied the effect of high-density polyethylene (HDPE) and crumb rubber powder (CRP) as a modifier enhance physical properties and marshall properties of asphalt. By adding HDPE and CRP resistance to moisture damage raised significantly [9]. Mansourian and Gholamzadeh improved the moisture susceptibility by using a new nanocomposite material ((polypropylene/nano-clay) with a percentage of 2% by weight of the binder. The indirect tensile strength and surface free energy test results were improved [10]. Hamedi and Tahami studied the influence of Zycosoil as an antistripping agent in bitumen modification for moisture susceptibility. Surface free energy test results showed that there was a reduction in the debonding energy of stripping phenomena [11]. Zaidi et al. conducted a comprehensive study of HL on moisture damage in bitumen mastic and asphalt mixture. The moisture damage assessment can be made by performing RBT, BBS test, etc. and asphalt concrete modified with HL showed improvement in adhesion and resistance to moisture damage [12].

Disposal of a large amount of waste material in the form of plastic and rubber tires is a serious environmental concern. Waste plastic and crumb rubber are commonly disposed off by landfilling and incineration hence causing serious

environmental damage. The use of these waste materials in asphalt mixture can help in solving these environmental problems and at the same time giving a more durable asphalt mixture.
The following are the objectives of this research work:

- To investigate the effect of waste plastic and crumb rubber on properties of bitumen.
- To investigate the effect of waste plastic and crumb rubber on properties of asphalt mixture in terms of adhesion and moisture damage.

2 EXPERIMENTAL AND RESEARCH METHODOLOGY

2.1 Material used

The bitumen used in this study is 60-70 Pen grade bitumen, which is a very common type of binder used in Pakistan. The aggregate from Margalla queries is obtained. PET is taken from Plastic bottles which are made from polyethylene Terephthalate, wash them, and grind bottles in shredder plants. CR is taken from used tires scrap and grind rubber tires in shredder plants. After shredding these materials passing through sieve No.50/300 Microns/0.297 mm.

2.2 Mixing Proportion

For making a blend, first, the bitumen is heated at 150ºC by placing it on the hot plate and constant temperature is maintained while PET and CR are added in it and the shear mixer is used for mixing at a speed of 1500 rpm for 40 minutes.

Table 1: Mixing proportion of PET and CR modified binder

Sr. No	Dosage	Mixing Time
1	Control +5% PET	40 minutes
2	Control +10% PET	40 minutes
3	Control +15% PET	40 minutes
4	Control +5% CR	40 minutes
5	Control +10% CR	40 minutes
6	Control +15% CR	40 minutes

2.3 Specimen Preparation and Testing Method

The effect of PET and CR binder was characterized by performing penetration and softening point test as per ASTM D5 [13], ASTM D36 [14] respectively. To investigate the bonding of bitumen with the aggregate after dry and wet condition PATTI (Pneumatic Adhesion Tensile Testing Instrument) was performed in terms of the BBS test as per ASTM D 4541 [15]. All samples were tested under dry and water cured conditions (24, 48, and 72 hours). The PET (5%, 10%, and 15%) and CR (5%,10% and 15%) by weight of binder were used in the control binder to check the bond strength of the bitumen aggregate system. The burst pressure at which stud detaches from the aggregate sample can be determined from PATTI which is then used in equation 1 to calculate Pull Off Tensile Strength (POTS).

$$POTS = \frac{(BP \times A_g) - C}{A_{ps}} \tag{1}$$

POTS is the pull-off tensile strength, BP is burst pressure
A_g is the contact area having a value of 2620 mm^2, C is the piston constant 0.286
A_{ps} is the area of pull-stub having a value of 127 mm^2, for this study F-4, stub type was used.
To investigate the moisture susceptibility of 60-70 pen grade, PET and CR modified binder, RBT as per BS EN 12697-11 [16] was performed. For the preparation of sample 170g aggregate and 8g bitumen was mixed. The bitumen coating on the sample was taken after 6, 24, 48, and 72 hours of rolling time.

The research methodology takes up for this work is given below in Figure 1.

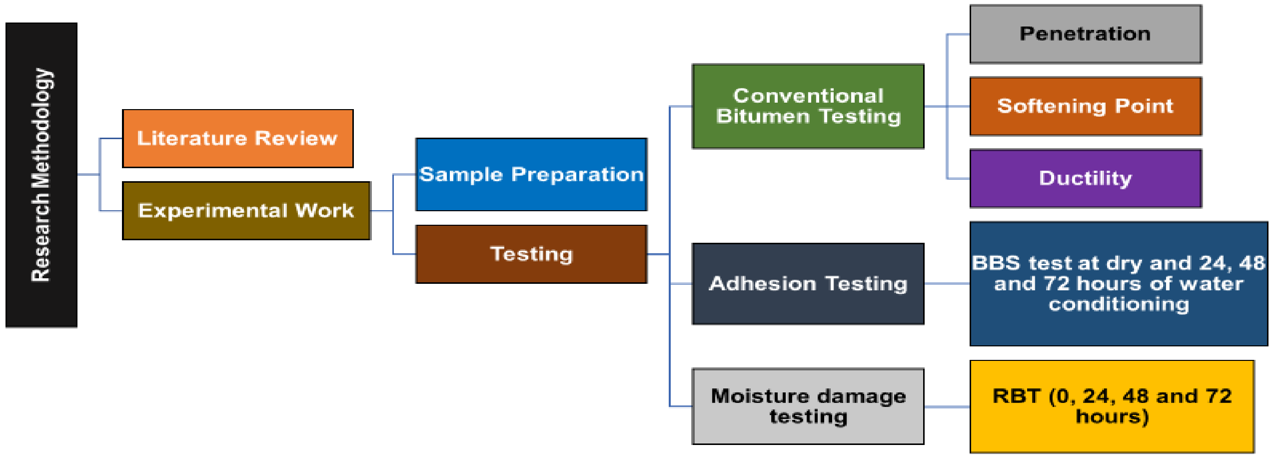


Figure 1: Research Methodology

3 RESULTS AND DISCUSSION

3.1 Conventional Testing

In this approach to study the effect of modifiers on bitumen conventional testing was performed. The purpose of performing penetration and softening point test are to check whether modified bitumen becomes soft or hard because softening and hardening of bitumen have a direct effect on adhesion and moisture damage [17]. The experimental results of conventional testing are shown in Figures 2.

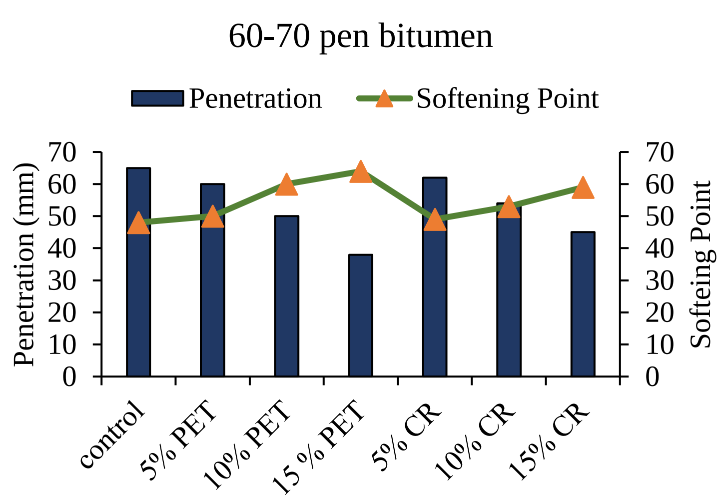


Figure 2: 60-70 pen grade modified and unmodified bitumen penetration and softening point values

The addition of 15% PET by weight of binder in 60-70 pen bitumen decreases the penetration value by 43%, whereas an increase of 34% in the softening point was observed as compared to the control binder. In 15% CR modified 60-70 pen bitumen a decrease of 32% in penetration value and an increase of 23% in value of softening point was observed as compared to the control binder.

Hence, as the dosage of PET and CR increases, penetration values decrease, and softening point increases which means the addition of PET and CR in 60-70 pen bitumen, the binder becomes harder. The addition of PET in binder makes the binder harder than CR.

3.2 *Evaluation of adhesion using BBS test*

In the experimental evaluation of the effects of PET and CR on adhesion, the Pneumatic Adhesion Tensile Testing Instrument (PATTI) was used. The main test advantage is that the adhesion between bitumen and aggregate can be found easily in the sense of force. The addition of 15% PET and CR by weight of binder in 60-70 pen bitumen 36% and 31% POTS values increase in dry condition compare to control binder respectively. The error bar in the figure-3 shows the positive mean deviation values from the 60-70 pen bitumen.

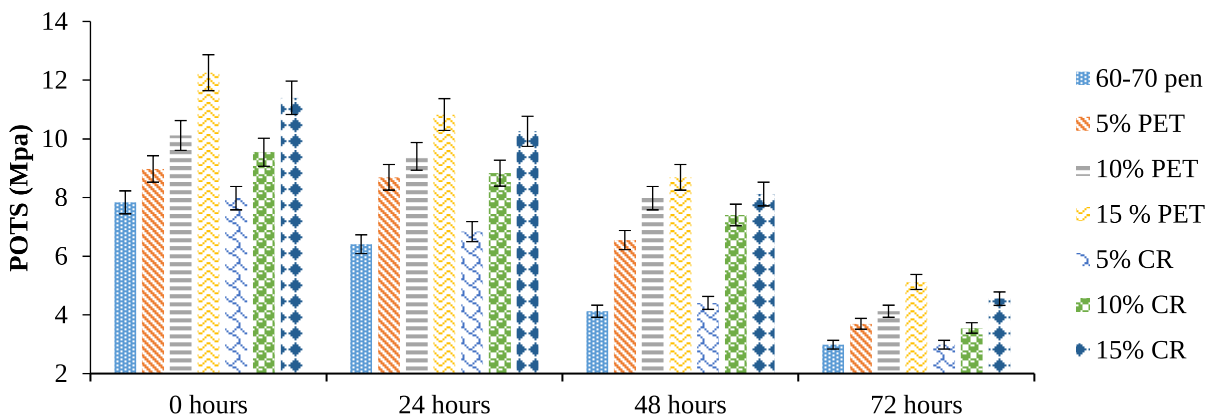


Figure 3: POTS values of 60-70 pen grade modified and unmodified bitumen at dry and wet conditioning

After 24, 48, and 72 hours of wet conditioning the POTS values of the PET and the CR decrease but remain higher than that of the control binder because the water penetrates the bitumen-bitumen interface and bitumen-aggregate interface which weakens the bond [18].

In 60-70 pen modified bitumen with the PET higher POTS values as compared to control binder were observed in dry conditions. But the PET modified bitumen showed lesser values after water conditioning as compared to dry conditions. CR shows lesser values of POTS in dry and water conditions as compared to PET but shows improved results as compared to the control binder.

3.3 *Failure surface analysis*

When stub detaches from the aggregate surface, there are two types of failures, one is an adhesive failure and the other is a cohesive failure. Visual identification of bitumen remains on aggregate sample determines the type of failure. When bitumen remains on the aggregate surface area greater than 50% then it is cohesive failure else it is an adhesive failure. In the case of 50% bitumen remains on aggregate the failure is cohesive-adhesive.

Table:2 60-70 pen Bitumen with the percentage of coverage area

	60-70 pen	5% PET	10% PET	15 % PET	5% CR	10% CR	15% CR
0 hours	70C	77C	70C	68C	71C	83C	87C
24 hours	59C	69C	61C	63C	67C	74C	76C
48 hours	50C/A	58.5C	49.9A	49A	50C/A	59C	63C
72 hours	30A	43A	38A	36A	39A	38A	41A

CT* curing time; A, adhesive failure; C, cohesive failure; C/A, 50% adhesive 50% cohesive failure

Table 1 shows the percentage of bitumen coverage and the failure type after dry and wet conditioning of the sample. In 60-70 pen bitumen modified by PET higher bond strength were achieved and failure changes from cohesive to adhesive after 24 hours of water conditioning. Whereas in 60-70 pen bitumen modified by CR show higher bond strength and failure changes directly from cohesive to adhesive after 48 hours of wet conditioning.

3.4 Moisture damage evaluation using RBT

Rolling bottle test was performed to measure the affinity between bitumen and aggregate. From figure 4, it can be concluded that the increase in rolling time decreases the bitumen coverage. PET and CR modified bitumen adhesion effects are clear as compared to the control binder. The 15% PET and CR modified binder increases 30% and 15% coverage as compared to control binder after 72 hours of rolling time. In the PET and the CR modified bitumen of the 60-70 pen grade adhesion effect is prominent in PET modified bitumen as compared to the CR and control binder.

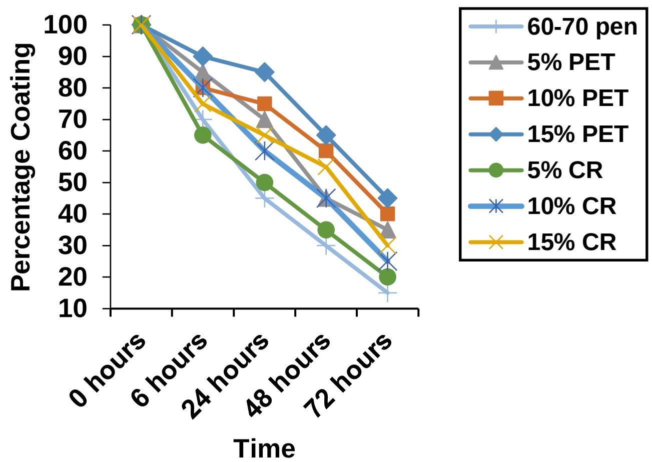


Figure 4: Comparison of the percentage of bitumen coverage of 60-70 modified and unmodified bitumen at different duration

4 CONCLUSION

The following conclusions have been drawn from the results obtained during the study.

- With the addition of 15% PET and CR, the penetration value decreases 43% and 32%, thus the softening point increase 34% and 23% respectively as compared to the 60-70 pen grade bitumen. Thus, the addition of PET and CR modified bitumen become hard thus penetration values decrease and softening point increases.

- The addition of 15% PET and CR in control binder POTS values increases by 36% and 31% respectively as compared to 60-70 pen bitumen at the dry condition. After 72 hours of water conditioning the POTS values of 60-70 pen bitumen, PET and CR modified binder decreased as compared to dry condition. Hence, PET modified binder shows higher POTS values as compared to the CR and 60-70 pen bitumen binder.

- By adding the amount of 15% PET and CR shows 30% and 15% more bitumen coverage as compared to the 60-70 pen bitumen binder. At 72 hours of rolling time, PET binder shows more bitumen coverage as compared to the CR and 60-70 pen bitumen binder.

ACKNOWLEDGMENT

The authors would like to thank the Taxila Institute of Transportation Engineering (TITE) University of Engineering and Technology, Taxila for providing the equipment in TITE Lab. The anonymous reviews are gratefully thanked for their close analysis and positive feedback.

REFERENCES

[1] M. J. Khattak and N. Peddapati, "Flexible Pavement Performance in relation to In Situ Mechanistic and Volumetric

Properties Using LTPP Data," vol. 2013, 2013.

[2] A. Ebrahim and A. E. Behiry, "Laboratory evaluation of resistance to moisture damage in asphalt mixtures," *Ain Shams Eng. J.*, vol. 4, no. 3, pp. 351–363, 2013.

[3] M. Porto, P. Caputo, V. Loise, S. Eskandarsefat, B. Teltayev, and C. O. Rossi, "Bitumen and Bitumen Modification : A Review on Latest Advances," pp. 1–35, 2019.

[4] H. I. Abdel-shafy and M. S. M. Mansour, "Solid waste issue : Sources , composition , disposal , recycling , and valorization," *Egypt. J. Pet.*, vol. 27, no. 4, pp. 1275–1290, 2018.

[5] M. R. Hassan, A. Al Mamun, M. I. Hossain, and M. Arifuzzaman, "Moisture Damage Modeling in Lime and Chemically Modified Asphalt at Nanolevel Using Ensemble Computational Intelligence," vol. 2018, 2018.

[6] E. Ahmadinia, M. Zargar, M. R. Karim, M. Abdelaziz, and E. Ahmadinia, "Performance evaluation of utilization of waste Polyethylene Terephthalate (PET) in stone mastic asphalt," *Constr. Build. Mater.*, vol. 36, pp. 984–989, 2012.

[7] Z. Leng, A. Sreeram, R. K. Padhan, and Z. Tan, "Value-added application of waste PET based additives in bituminous mixtures containing high percentage of reclaimed asphalt pavement (RAP)," *J. Clean. Prod.*, vol. 196, pp. 615–625, 2018.

[8] M. Fakhri, S. Javadi, R. Sedghi, D. Arzjani, and Y. Zarrinpour, "Effects of deicing agents on moisture susceptibility of the WMA containing recycled crumb rubber," *Constr. Build. Mater.*, vol. 227, p. 116581, 2019.

[9] H. A. A. Gibreil and C. P. Feng, "Effects of high-density polyethylene and crumb rubber powder as modifiers on properties of hot mix asphalt," *Constr. Build. Mater.*, vol. 142, pp. 101–108, 2017.

[10] A. Mansourian and S. Gholamzadeh, "Moisture susceptibility of hot mix asphalt containing asphalt binder modified with nanocomposite," *Road Mater. Pavement Des.*, vol. 18, no. 6, pp. 1434–1447, 2017.

[11] G. H. Hamedi and S. A. Tahami, "The effect of using anti-stripping additives on moisture damage of hot mix asphalt," *Int. J. Adhes. Adhes.*, vol. 81, no. January 2018, pp. 90–97, 2018.

[12] S. Bilal and A. Zaidi, "The influence of hydrated lime on moisture susceptibility of asphalt mixtures," no. February, 2018.

[13] D. ASTM, "Standard test method for penetration of bituminous materials," *USA, ASTM Int.*, 2013.

[14] ASTM, "Astm D 36," *"Standard Test Method Softening Point Bitumen", ASTM Int. West Conshohocken, PA, USA.*, vol. 1, no. d, pp. 3–6, 2006.

[15] ASTM, "D4541 - 02: Standard test method for pull-off strength of coatings using portable adhesion testers," in *ASTM International*, 2009, no. April, p. 16 p.

[16] "BSI Standards Publication Bituminous mixtures — Test methods for hot mix asphalt Part 11 : Determination of the affinity between aggregate and bitumen," 2012.

[17] H. Ali, N. Izzi, H. Ceylan, Z. Sajuri, and F. Mohd, "Investigation of the relationship between fluidity and adhesion strength of unmodified and modified bitumens using the pull-off test method," *Constr. Build. Mater.*, vol. 122, pp. 140–148, 2016.

[18] R. Moraes, R. Velasquez, and H. U. Bahia, "Measuring the Effect of Moisture on Asphalt – Aggregate Bond with the Bitumen Bond Strength Test," pp. 70–81.

EXPERIMENTAL STUDY OF SHRINKAGE IN MUD BRICKS AND ITS CONTROL

[a*] Mudassir Qasim, [b] Mohammad Adil, [c] Hassan Shahzad, [d] Muhammad Wasim
Department of Civil Engineering, University of Engineering and Technology, Peshawar, KP, Pakistan,
[a]*17pwciv4950@uetpeshawar.edu.pk, [b] adil@uetpeshawar.edu.pk, [c] awadhaasan@gmail.com, [d] mmm.wasim936@gmail.com

Abstract- Shrinkage in mud Adobe-Buildings is one of the major issues, need to be consider before the construction. Cracks formation occurs during shrinkage is the result of water evaporation from the mud. Cracking in any materials can lead to a pattern formation over a wide range of length scale from microscopic to macroscopic. It is unwanted phenomena often result in the abandonment of the technological process. Many researchers solve this process up to some extent but yet to overcome on it. In this study Poly Vinyl Alcohol (PVA) is used in some specific proportion with water to minimize the shrinkage and maximize the strength of adobe construction. The performance of different laboratory tests helps to determine the specific ratio of chemical stabilizer with soil through which the shrinkage get reduced to control cracks. The results show that chemical stabilizer used have reduced the shrinkage in the mud beam up to 3.02%.

Keywords- Adobe Bricks, Chemicals Ratio, Shrinkage, Sustainable Development

1 INTRODUCTION

Around 36% of the Pakistan's population lives in buildings made up of earth materials [1]. The world is facing environmental problems such as carbon emissions, which create different health issues; moreover, the world approaching towards marvelous sky scrapers which is equally environmental non-friendly materials [2]. The problem caused by non-Eco-friendly construction materials like corrugated iron sheet, fired clay bricks, wood; bamboo and concrete are mitigated by earthen construction. Cement used as stabilizer can improve the strength but are not effective in improving the ductility. [3]. Mud is considered as a user friendly from ancient time and is accepted environment friendly universally [4]. Mud bricks are considered one of the oldest construction materials, engineers and builders do not have enough information about its mechanical properties [5]. When seeing into different types of mud construction, they have different types of cracks appearance after sometimes. There are three different typologies of adobe bricks in terms of their internal soil element proportions and some organic content [6]. The linear shrinkage crack formation in the mud decreases with increase of fiber content in soil at specific proportion [7]. This research paper aims to find out the optimum ratio of the chemical stabilizer at which there is minimum shrinkage cracks to occur with achieving better strength and minimum shrinkage to use it for structural buildings, which will be environment friendly, energy efficient and economical.

2 MATERIALS AND SAMPLE PREPARATION

In this research different types of materials are used having specific properties and behaviors and different samples were prepared to investigate the optimum water and stabilizer content on which there is minimum shrinkage occur.

2.1 Materials used

The materials used during this research is chemical stabilizer, water and locally available soil of Zangali area near Peshawar. The chemical stabilizer Poly Vinyl Alcohol (PVA) is nontoxic. It is resistant to oil and grease, having high tensile strength and flexibility, in this study the synthetic polymer is soluble in water and is biodegradable under both aerobic and anaerobic conditions. The portable water in the university premises is used. The test performed for the determination of liquid limit plastic limit and plasticity index is an accordance with ASTM D4318 as in [8]. The result is in the form of table.

Determination of liquid limit plastic limit and plasticity index	
Liquid limit	23.5%
Plastic limit	37%
Plasticity index	0

2.2 *Sample Preparation*

Sample preparation involves the gradation of soil, making solution of chemical with water and then it's mixing. Each of them is discussed below.

2.3 *Gradation*

The locally available Zangali soil can be seen from figure 1, which are passed through sieve no# 08 before use.

Figure 3: Zangali soil passed through sieve no # 8

2.4 *Solution making*

The solution is prepared by the mixing of water with chemical stabilizer at specific proportion by continuous shaking for at least 1 minute in a glass container.

Figure 4: Liquid solution of water and stabilizer

2.5 *Mix preparation*

At end the solution was poured into soil and kneading and crushing it with fingers for at least 15 minutes.

3 RESEARCH METHODOLOGY

In order to tackle with the control of shrinkage in super mud, first find out the proportion of all ingredients in specific ratio (mix design) and then moves towards testing the specimens.

3.1 Mix design

The main aim of the mix design is to find out specific quantity of different ingredients and determines their relative proportion to achieve minimum shrinkage and give optimum strength, durability and equally as economical as well.

3.2 Linear Shrinkage test

The linear shrinkage beam of internal dimensions 11.25*2*2inch is used for shrinkage test. This test is conducted to determine the change in length of mortar beam as it is drying at room temperature. The mix proportions prepared are put in the mortar beam in three equal layers with hands in mortar beam as the stabilizer is not toxic. Three samples of mortar beam named as Z-1, Z-2, and Z-3 are made respectively. Then taking the daily reading of these samples including the loss of weights, linear shrinkage and also take the daily reading after 24 hours of humidity and temperatures with digital hygrometer.

Figure 5: Linear shrinkage mortar beam Z-1

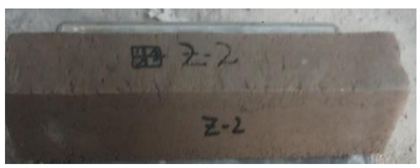


Figure 6: linear shrinkage mortar beam Z-2

Figure 7: linear shrinkage mortar beam Z-3

4 RESULT

The water loss and shrinkage occur in the mortar beam versus temperature and humidity is shown in figure 6.

4.1 Shrinkage test

The procedure used for this test was as per **ASTM C596** used in [9]. Graphical representation of the shrinkage test values is illustrated in figure 6. The x-axis shows the time in days, on the right y-axis shows the shrinkage limit and the left y-axis shows temperature of the place in which sample is placed. The graph shows that the shrinkage in the mud beam increases with time due to water loss and reach maximum of 3.55% at day eleven and then shows a gradual decrease after that due to temperature increase as shown in the figure. The flat curves start appear after 23rd day and the shrinkage percentage were 3.02% at the day 28.

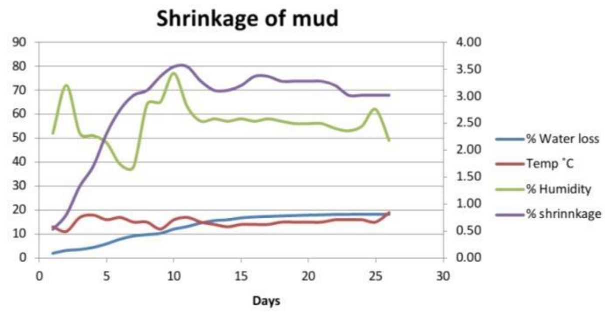


Figure 8: Times vs shrinkage in mortar beam

5 CONCLUSION

The shrinkage of Zangali site soil is examined in this study. More than 30 trials were conducted to find out that optimum ratio on which there is minimum shrinkage and durable samples. Following conclusions can be drawn from the conducted study:

- The shrinkage in mortar beam were gradually increases with time due to water loss and reach maximum of 3.55% with transverse crack.
- The experimental results show that as the water loss increases the shrinkage in the mud beam also increases, and finally the linear shrinkage was 3.02% with no or few small cracks.
- Mud construction has important role to protect the world from climate change and having safe and unpolluted environment.

ACKNOWLEDGMENT

The authors would like to thank every person who helped us thorough out the research work, particularly the research environment and infrastructure provided by Department of Civil Engineering, University of Engineering and Technology, Peshawar. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] Khan A, Adil M, Naseer A, Rahman U.,. Mechanical properties of different stabilized soils of Khyber Pakhtunkhwa. 4th international multidisciplinary research conference on global prosperity through research and development 9-11 October 2018, at Sarhad University of science and information technology Peshawar (IMRC-2018)

[2] Lekshmi, M., Vishnudas, S. and Nair, D., 2017. An investigation on the potential of mud as sustainable building material in the context of Kerala. International Journal of Energy Technology and Policy, 13(1/2), p.107.

[3] [3] Islam S., Hossain I., Islam A., Shahriar R., Bose B. Construction of Earthen Housing Using CSEB. Bangladesh Perspective. 3rd International Conference on Advances in Civil Engineering, 21-23 December 2016, CUET, Chittagong, Bangladesh

[4] Lekshmi, M., Vishnudas, S. and Nair, D., 2017. An investigation on the potential of mud as sustainable building material in the context of Kerala. International Journal of Energy Technology and Policy, 13(1/2), p.107.

[5] Al-Ajmi, F., Abdalla, H., Abdelghaffar, M. and Almatawah, J., 2016. Strength Behavior of Mud Brick in Building Construction. Open Journal of Civil Engineering, 06(03), pp.482-494.

[6] Piani, T., Krabbenborg, D., Weerheijm, J., Koene, L. and Sluijs, L., 2018. The mechanical performance of traditional adobe masonry components: an experimental-analytical characterization of soil bricks and mud mortar. Journal of Green Building, 13(3), pp.17-44 Ashour, T. and Wu, W., 2010. An experimental study on shrinkage of earth plaster with natural fibres for straw bale buildings. International Journal of Sustainable Engineering, 3(4), pp.299-304.

[7] Kayabali K., 2012. Estimation of liquid, plastic and shrinkage limits using one simple tool. Electrical journal of Geotechnical Engineering, 17

[8] Hasan Z., 2016. Investigation of drying shrinkage and compressive strength of cement mortar with partial replacement of cement by egg shell powder and milled glass. Al-Qadisiyah journal of Engineering sciences, 9, 316-330.

STABILITY ANALYSIS OF SLOPES USING LIMIT EQUILIBRIUM AND FINITE ELEMENT METHODS

[a*]Sohaib Naseer, [b]Robert Evans
[a &b] School of Architectural, Design and Built Environment, Nottingham Trent University, UK
[a*]sohaib.naseer2019@my.ntu.ac.uk

Abstract- The stability of natural and manmade slopes is a common geotechnical problem. Due to its importance, the analysis of slope stability has received wide attention in literature. Various methods have been developed to analyze slope stability each of which is based on different assumptions and conditions. Each technique has some advantages and limitations. This paper compares the factor of safety and failure surfaces of slopes obtained by limit equilibrium and finite element method. For this purpose, Rocscience SLIDE 6.0 for limit equilibrium (LE) and PLAXIS for finite element (FE) analysis was used. The safety factors were calculated for different slope geometry and soil types. A comparison was made among the slip surfaces and factor of safety values obtained using both approaches. It was concluded that LE approach, estimated a higher factor of safety as compared to the FE approach. Also, significant variation is found is the failure surfaces as determined from both approaches.

Keywords- Slope Stability, Limit Equilibrium, Finite Element Method, PLAXIS, Rocscience Slide 6.0

1 INTRODUCTION

Landslides or slope failures are the major threats to both human lives as well as property. The adequate assessment of slopes is a major concern of geotechnical engineers that how close or far the slopes are from failure. To investigate the factor of safety for slope, various methods have been introduced by the researchers. The earliest studies appeared in the 1970s (e.g., [1]; [2]; [3]; [4]) and have continued steadily (e.g., [5]; [6]; [7]; [8] [9]). However, in recent years, due to the development in the field of computational methods, various software programs have been developed for the slope stability analysis ([10]; [11]; [12]). The stability methods are commonly categorized in two major groups. The one is Limit Equilibrium Method~~s~~ (LEM) and other is numerical analysis. The LEM is based on creating the balance conditions of driving and resisting forces acting on a slope. The slope will be in stable condition when the resisting forces (internal forces of slopes) are equal to more than the driving forces (external forces applied on slope including the self-weight of slope). Numerical analysis is based on dividing the slopes in finite number of elements and zones. Afterward, forces and displacement/strains are calculated using the constitutive laws in the slope. The numerical analysis methods are further divided into different techniques which included Finite Element Methods (FEM), Discrete Element Methods (DEM) and Boundary Element Methods (BEM) [13]. In this paper, the analysis of slope stability was carried out using limit equilibrium method and finite element method. The factor of safety obtained from these methods are then compared. Furthermore, the mode of slope failure is investigated using both methods, and effect of surcharge on stability of slope was also examined.

2 LIMIT EQUILIBRIUM METHOD

The analysis of slopes using the Limit Equilibrium Method (LEM) has been significantly refined by using various methods of vertical slices. It is based on the most common five limiting equilibrium methods for determining the safety factor, i.e., ordinary or Fellenius method [14], Bishop's simplified method [15], Janbu's simplified method [16], Spencer's method [17] and the Generalized Limiting Equilibrium (GLE) or Morgenstern–Price method [18]. Limit Equilibrium (LE) methods use the Mohr-Coulomb failure criterion to determine the shear strength along the slip surface. A state of limit equilibrium exists when the mobilized shear stress is expressed as a fraction of the shear strength. In LE analysis, the sliding mass is divided into slices, determination of the shear and normal inter-slice forces is made, and appropriate force and/or moment equilibrium equations are satisfied for static equilibrium conditions. The first LE method for a round slip surface was presented by Fellenius [14]. Bishop [15] later developed a revised method of circular slip analysis. Meanwhile, Janbu [16] presented a technique for non-circular failure surfaces that isolated a potential sliding mass into a few vertical slices. Later techniques were developed by Morgenstern-Price [18], Spencer [17], Sarma [19] and a few others to make further advances with regards to the various assumptions about inter-slice forces. The LE methods chosen for this study included Bishop's Simplified Method (BSM), Janbu's Simplified Method (JSM), and Spencer's Method (SM). These methods are commonly used due to relatively adequate accuracy while calculating the FOS.

3 FINITE ELEMENT METHOD

Numerical modelling is considered a dominant tool to solve the complex engineering problems and has become increasingly popular in geotechnical engineering analysis. The two most common types of numerical methods are Finite Element (FE) and Finite Different (FD) methods. The finite element (FE) method, discussed in this paper, uses the soil stress-strain behaviour for slope stability modelling. The major factor which considered as advantage of finite element analysis is that no assumptions are required for the slip surface and shape of the slope. The FE approach divides the model into a number of pieces or elements of a mesh. Stresses and strains are calculated using the constitutive laws for materials comprising of the slope stability model. Failure occurs naturally through the zones in which the soil shear strength is unable to sustain the developed shear stresses. Ultimately, a Reduction Factor (RF) can be calculated for finite element methods using the 'c-φ reduction' method. This approach requires incrementally reduced soil strength parameters until the failure occurs. The shear strength reduction technique enables the FE method to calculate FOS for slope.

4 SLOPE MODEL

4.1 Slope Geometry

It is well understood that stability of slope is a direct function of the height and gradient of slope, as well as material properties of the soil/rock material. For purposes of this study, a simple slope section was modelled with combinations of several different slope heights and gradients with a variety of different soil types. Four different slope gradients (β) of 1H:1V, 1.5H:1V, 1.75H:1V & 2H:1V were modelled at three different heights (H) of 7m, 12m & 17m, resulting in a total of twelve (12) different combinations of slope geometry. The base of the slope model was assumed to be rigid (or bedrock).

4.2 Soil properties

Four different soil types with unique assumptive soil properties were modelled as homogenous materials for slope stability analyses using both LE and FE methods. The selection of these soil types was intended to provide a wide array of strength characteristics ranging from cohesionless to purely cohesive soils, modelled as loose/soft and dense/hard. Table 1 provides a summary of the parameters used to create the various soil types for purposes of this study.

Table 1: Soil types and assumed elastic/plastic parameters for study

Sr. No.	Soil Type	Soil ID	μ	E (MPa)	ɣ (kN/m^3)	c (kPa)	Φ (degree)
1	Soft Sandy Clay (SC)	S_1	0.30	25	16.50	20	21
2	Stiff Sandy Clay (SC)	S_2	0.25	100	18.00	50	24
3	Soft Clay (CL)	S_3	0.4	18	16.00	10	0
4	Stiff Clay (CL)	S_4	0.35	40	17.00	30	0

5 ANALYSIS APPROACHES

5.1 Limit Equilibrium Analysis

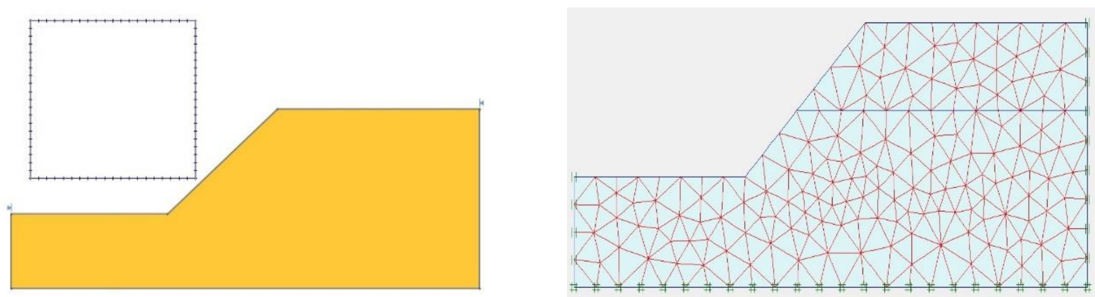
Limit equilibrium (LE) analysis was performed by the commercially available LE tool SLIDE software, advanced by Rocscience, Inc. It is a two-dimensional computer program, which can be used to evaluate the stability of circular or non-circular failure surfaces. SLIDE is widely used in the engineering world for relatively quick and easy computations of a variety of different slope configurations. Computations of FOS in SLIDE were based on the Mohr-Coulomb failure criterion without tension cracks. The model requires basic strength parameters such as the angle of internal friction (φ) and cohesion (c). Figure 1(a) shows the typical auto grid generated for determination of critical slip surface in Slide.

5.2 Finite Element Analysis

Commercially available finite element tool, PLAXIS is used for two dimensional FE analysis. The safety factor in PLAXIS is determined using strength reduction method, also known as ϕ-c reduction method. In this approach, shear strength parameters (ϕ and c) of the soils are successively reduced until failure occurs. PLAXIS uses a total multiplier parameter ΣM_{sf} to define the value of the shear strength parameters at a given stage and calculates the safety factor (SF) from the value of ΣM_{sf} which is equal to the available strength divided by the strength at failure:

Safety Factor= (resisting strength)/ (driving strength) $=\sum M_{sf}$ at ***failure*** ------------------- Equation (1)

Figure 1(b) shows the typical mesh generated for determination of finite element analysis in PLAXIS.

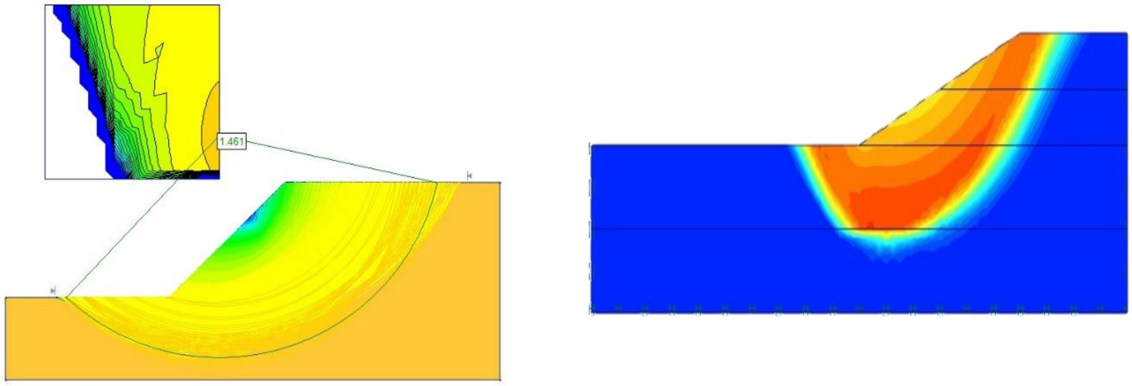


(a) (b)

Figure 1: (a) Typical auto-grid generated by Slide for slip surface. (b) typical mesh generated using PLAXIS 2D

6 RESULTS AND DISCUSSIONS

The slope stability analysis were performed on 4 different soils with 4 slope angles with 3 different slope heights using LEM and FEM method. BSM, JSM and GLE methods were used to determine the safety factor in LEM, while in FEM, strength reduction method was adopted for calculation of safety factor. The results are summarized in Table 2 – Table 5. Figure 2 illustrate the critical failure surface developed in slide and PLAXIS analysis. Figure 3 shows the comparison of safety factor determined using different approaches in LEM and FEM for various geometrical and soil conditions. It was observed that LE overestimate the safety factors as compared to FE. LE estimated the factors of safety about 20% -30% more than the FE in all cases. Also, among the different approaches used in LE, the BSM calculated the higher values as compared to JSM. The reasons for this variations are the analysis mechanism of all LE methods. Every method have some assumptions, e.g. BSM did not consider the vertical forces between the slices, whereas, in JSM and GLE methods, the inter-slices vertical forces and individual slice momenta are considered which estimate the higher value of safety factors. Furthermore, it can be seen that, stiff soils shown more resistance towards the failure and hence gave higher values of safety factors as compared to the soft soils. The stiff soils have more tendency to resist the applied forces and hence produces more resistance at the failure surfaces because of higher shear strength characteristics. Among the all soil types, the stiff sandy clay (S_B) shown the maximum resistance whereas, soft clay (S_D) gave the minimum values of safety factor in all geometrical conditions. Also, factor of safety decreases for steep slopes in both LE and FE analysis. When the height of slope is increased, there is significant drop in the factor of safety in both approaches.



a) b)

Figure 2: Typical slip surface developed using (a) LEM and (b) FEM

Table 2. Calculated FOS for critical surface using LEM and FEM for slope = 1H: 1V

Soil Type	Slope Height = 7 m				Slope Height = 12 m				Slope Height = 17 m			
	LEM			FEM	LEM			FEM	LEM			FEM
	BSM	JSM	GLE		BSM	JSM	GLE		BSM	JSM	GLE	
S_1	1.80	1.79	1.82	1.12	1.33	1.28	1.32	0.98	1.12	1.07	1.12	0.87
S_2	3.29	3.26	3.29	2.50	2.26	2.22	2.26	1.75	1.84	1.78	1.83	1.00
S_3	0.52	0.51	0.52	0.10	0.32	0.35	0.37	0.10	0.22	0.23	0.23	0.10
S_4	1.46	1.45	1.46	0.90	0.91	0.99	1.05	0.65	0.62	0.65	0.66	0.30

Table 3. Calculated FOS for critical surface using LEM and FEM for slope = 1.5H:1V

Soil Type	Slope Height = 7 m				Slope Height = 12 m				Slope Height = 17 m			
	LEM			FEM	LEM			FEM	LEM			FEM
	BSM	JSM	GLE		BSM	JSM	GLE		BSM	JSM	GLE	
S_1	1.97	1.89	1.96	1.35	2.82	2.54	2.82	1.95	1.40	1.29	1.39	0.90
S_2	3.52	3.45	3.52	2.20	4.79	4.31	4.78	3.20	2.23	2.08	2.23	1.65
S_3	0.52	0.51	0.52	0.20	0.66	0.63	0.65	0.30	0.27	0.29	0.28	0.15
S_4	1.46	1.43	1.46	1.00	1.85	1.79	1.86	1.20	0.75	0.81	0.81	0.50

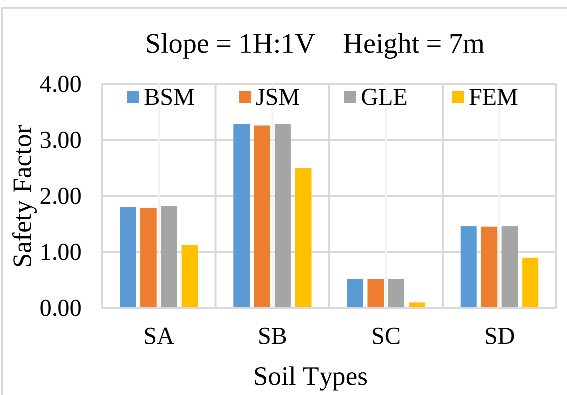
Table 4. Calculated FOS for critical surface using LEM and FEM for slope = 1.75H:1V

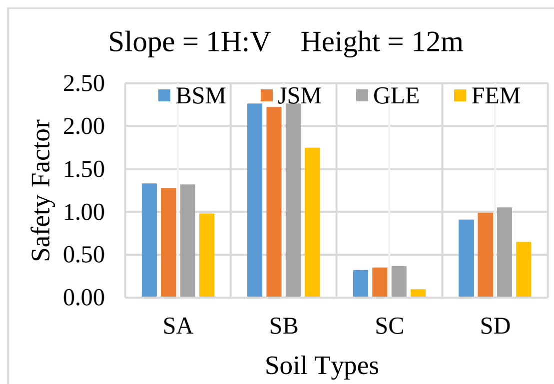
Soil Type	Slope Height = 7 m				Slope Height = 12 m				Slope Height = 17 m			
	LEM			FEM	LEM			FEM	LEM			FEM
	BSM	JSM	GLE		BSM	JSM	GLE		BSM	JSM	GLE	
S_1	2.34	2.17	2.33	1.75	3.30	2.94	3.29	2.10	1.60	1.47	1.60	0.75

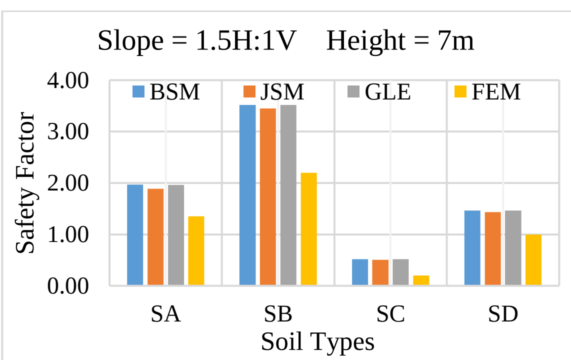
S_2	4.08	3.80	4.08	2.75	5.59	5.01	5.58	3.80	2.59	2.41	2.58	1.85
S_3	0.55	0.53	0.55	0.25	0.78	0.74	0.78	0.35	0.33	0.35	0.35	0.20
S_4	1.56	1.51	1.56	1.10	2.20	2.10	2.20	1.50	0.92	0.99	1.00	0.60

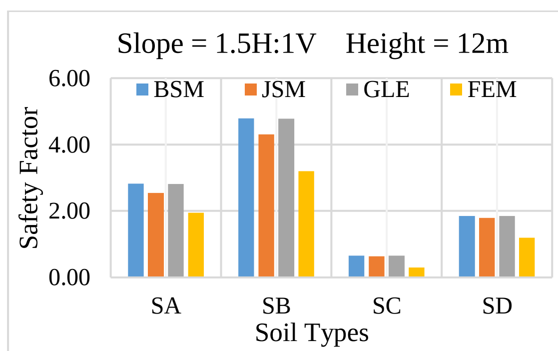
Table 5. Calculated FOS for critical surface using LEM and FEM for slope = 2H: 1V

Soil Type	Slope Height = 7 m				Slope Height = 12 m				Slope Height = 17 m			
	LEM			FEM	LEM			FEM	LEM			FEM
	BSM	JSM	GLE		BSM	JSM	GLE		BSM	JSM	GLE	
S_1	2.48	2.29	2.47	1.80	3.24	2.92	3.23	2.20	1.64	1.51	1.63	0.80
S_2	1.12	1.07	1.12	0.87	5.22	4.68	5.21	4.10	2.54	2.32	2.54	1.90
S_3	0.58	0.55	0.58	0.30	0.63	0.59	0.63	0.30	0.27	0.27	0.27	0.15
S_4	1.63	1.56	1.63	1.20	1.79	1.67	1.79	1.30	0.76	0.75	0.75	0.55









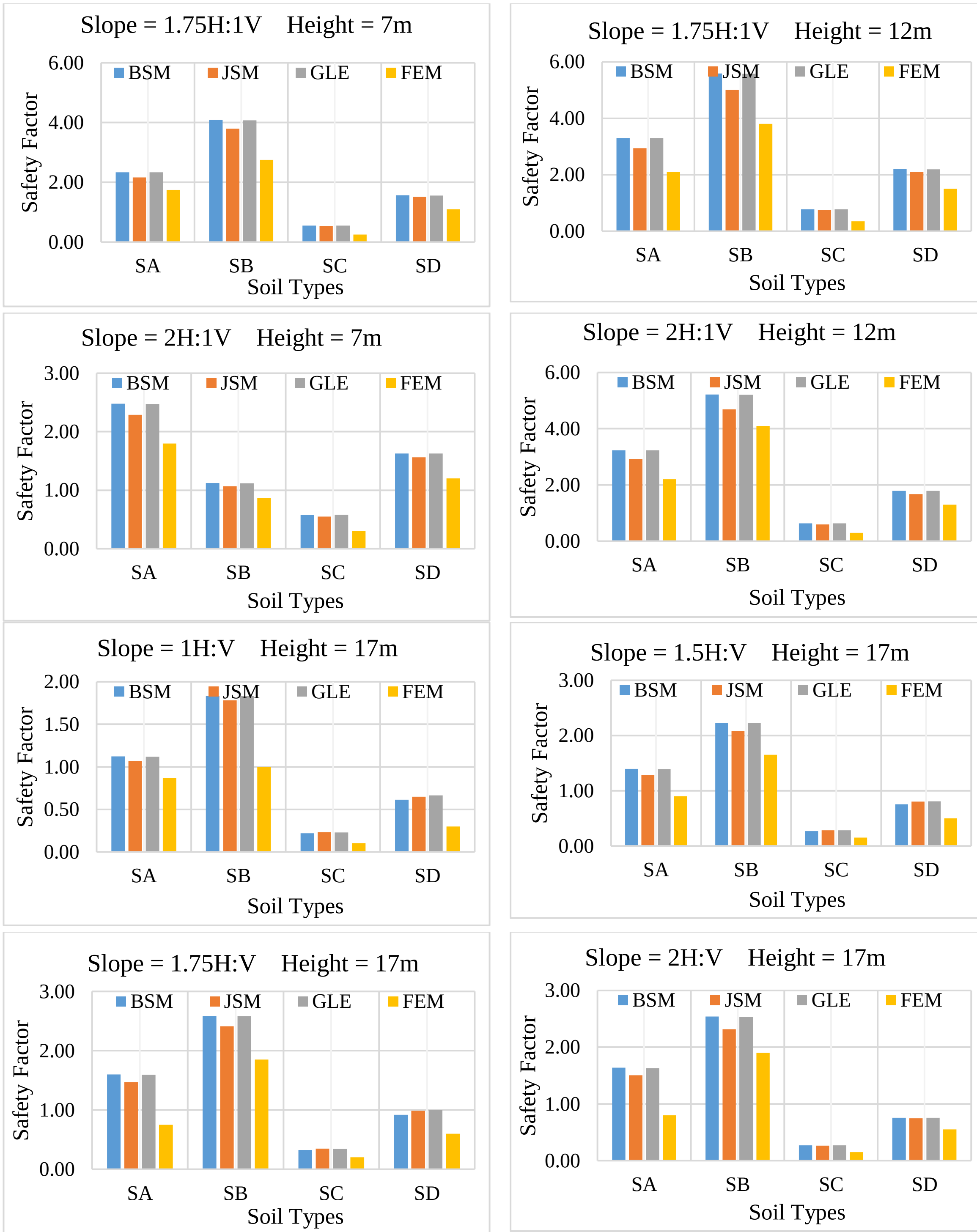


Figure 3: Comparison of safety factors calculated using LEM and FEM for different slope geometry and soil types

7 CONCLUSION

In general, LE methods are used for slope stability analysis by the practicing engineers and professionals. These methods provide rationally reliable values for safety factors, but LE methods are lacked in stress-strain behaviour and thus are not suitable for realistic analysis of complex slopes. This issue has been resolved by FE techniques for analysis which are based on fundamental principles of stress-strain behaviour. Both approaches have certain advantages and limitations and can be used for determination of slip surface and safety factors for slope. However, the similar studies have confirmed the vigorous nature of FE approach. Based on the current study, following conclusion are made:

- In general, the LE and FE methods used in this study provide fairly consistent FOS. When comparing relatively similar critical failure surfaces between the LE and FE methods, FE analyses show higher concentrations of plastic strain near the toe of the slope.
- The critical slip surface developed in FE is near the slope face, but in LE, the critical slip surface is found at far away from the slope face.
- The FE consider the interface strength which affects the factor of safety, whereas, the LE does not consider the interface strength that ultimately depicts in the calculated values of safety factor as shown in above sections.
- Although slope geometry plays a significant role in determining safety factors for stability of slopes, soil shear strength properties dominate as the primary-most factor in computing safety factors and producing unique failure surfaces.
- The stability of slopes in less cohesive soils is controlled by shallow surficial failures. Hence, slope gradient (β) is the primary factor in determining safety factors for cohesionless soils. Relatively similar critical failure surfaces were noted between the LE and FE methods for cohesionless sands. Slope stability analyses of purely cohesive soils result in deep-seated critical failure surfaces. Slope height (H) was observed to be the primary aspect of slope geometry affecting slope stability of clayey soils. FOS computed for these soils were notably higher than the equivalent RF. The LE method resulted in a relatively defined critical failure surface, whereas the FE method showed a much wider zone of critical failure.

REFERENCES

[1] Matsuo, M., and Kuroda, K. "Probabilistic approach to the design of embankments." Soil Found, 14(1), 1-17, 1974.

[2] Alonso, E.E. "Risk analysis of slope and its application to slope in Canadian sensitive clays." Geotechnique, 26, 453- 472.,1976

[3] Tang, W.H., Yuceman, M.S., and Ang, A.H.S. "Probability based short-term design of slopes." Can.Geotech. J.13, 201-215, 1976.

[4] Vanmarcke, E.H. "Probabilistic modeling of soil Profiles." ASCE J. Geotech, Eng., 103(GT 11). 1227-1246, 1977.

[5] D'Andrea, R.A. and Sangrey, D.A. "Safety factors for probabilistic slope design" ASCE J.Geotech. Eng., 108(GT9), 1101-1118,1982.

[6] Duncan, J.M. "Factor of safety and reliability in geotechnical engineering,." ASCE. J.Geotech. Geoenv. Eng., 126(4), 307- 316, 2000

[7] E.I.-Ramly, H., Morgenstern, N.R., and Cruden, D.M. "Probabilistic slope stability analysis for practice" Can. Geotech. J.,39, 665-683., 2002.

[8] Griffiths, D.V. and Fenton G.A. "Probabilistic Methods in Geotechnical Engineering". Springer, Wien, New York, CISM Courses and Lectures No. 491, International Centre for Mechanical Sciences., 2007

[9] Fenton, G. A., and Griffiths, D. V. "Risk Assessment in Geotechnical Engineering." John Wiley & Sons, Hoboken, New Jersey,2008.

[10] Namder, A. (2010) "Analysis of slope stability using limit equilibrium." Mysore University, pp. 75-84.

[11] He, B. and Zhang, H. (2012) "Stability analysis of slope based on finite element method." I.J Engineering and Manufacturing, Vol.3, 70-74.

[12] Lin, H. and Cao, P. (2012) "Limit equilibrium analysis for the relationships among slope c, and slip surface." Etectronic journal of geotechnical engineering, Vol.17, 185-195

[13] Kanjanakul, C., & Chub-uppakarn, T. Comparison between numerical and limit equilibrium methods for slope stability analysis. In 18th National Conference on Civil Engineering (NCCE), 104-110, 2013.

[14] Fellenius, W. Calculation of the Stability of Earth Dams, Trans. 2nd Cong. on Large Dams, Vol. 4, p. 445, 1936)

[15] Bishop, Alan W. "The use of the slip circle in the stability analysis of slopes." Geotechnique 5, no. 1 , 7-17, 1955.
[16] Janbu, N. Stability analysis of Slopes with Dimensionless Parameters. Thesis for the Doctor of Science in the Field of Civil Engineering, Harvard University Soil Mechanics Series, No. 46, 1954.
[17] Spencer, E. A method of Analysis of the Stability of Embankments, Assuming Parallel Interslice Forces. Geotechnique, Vol. 17, pp. 11-26, 1967.
[18] Morgenstern, N., and Price, V.E., The Analysis of the Stability of General Slip Surfaces, Geotechnique, Vol. 15, No. 1, pp.79-93, 1965.
[19] Sarma, S.K. Stability analysis of embankments and slopes, Geotechnique, Vol. 23, No. 3, pp. 423-433, 1973.

INVESTIGATING THE SUITABILITY OF IN-SITU SOILS OF PESHAWAR FOR UN-STABILIZED RAMMED EARTH CONSTRUCTION

a Amina Durrani, b Mohammad Adil, c Mohammad Wasim
a: National Institute of Urban Infrastructure Planning, University of Engineering and Technology, Peshawar, adurrani78@gmail.com
b: Department of Civil Engineering, University of Engineering and Technology, Peshawar, adil@uetpeshawar.edu.pk
c: Department of Civil Engineering, University of Engineering and Technology, Peshawar

Abstract- Rammed earth building is a sustainable solution globally. Particularly when built utilizing local soils it reduces the carbon footprint. The time-tested examples of traditional rammed earth constructions and the achievements/accomplishments of contemporary rammed earth constructions is appealing. Though remarkable buildings are being constructed by a handful of experts yet the data supported knowledge base and expertise is scarce locally. Other than careful design detailing and controlled construction, material suitability plays a vital role in its success. For sustainable earth building construction with the optimum use of material resource, soil suitability must be determined. In this research, five random soil samples from all around Peshawar were selected and their suitability for un-stabilized rammed earth application was investigated according to NZS 4298:1998. All the specimens failed the compression and wet-dry appraisal tests. All the specimens passed the Geelong Drip Test. S1, S2 and S4 passed the spray erosion test and S5 passed the linear shrinkage test. No soil specimen passed all the tests suggested by the standard for rammed earth construction. Hence silty-clayey soils of Peshawar with approx. 985 kN-m/m^3 compactive effort at optimum moisture content (OMC) was found to be not suitable for rammed earth application according to NZS 4298:1998.

Keywords- Earth building, Earth construction, Soil suitability, Un-stabilized rammed earth

1 INTRODUCTION

Rammed earth (RE) construction is one of the earthen building techniques that is gaining popularity globally. In this technique thick monolithic walls are directly produced by ramming moist soil (around OMC) in a bottomless formwork with the help of tampers or vibrators until a ringing sound is heard. Such structures do not require the use of mortar or plasters. In this method the void ratio is reduced and the density of the soil increases. This technique is also known as pisé de terre or simple pisé in France [1]– [3]. There are many multi-storied examples of this technique found in both hot and cold climates [2]– [5]. The Hakka Tulou in Fujian Province are one of the popular and ancient forms of such examples [6]. Now-a-days stabilized rammed earth (SRE) structures with fine finish are gaining popularity [4], [7].

For sustainable practices, earthen construction requires to be carried out with locally available materials. This drastically reduces the environmental impact of constructions [8]. To achieve better quality constructions, material selection, that is soil selection, with appropriate properties is an essential step [9]. Globally, in different regions there are soils that are suitable for a certain type of earthen construction and such constructions with good maintenance have lasted for centuries. Generally, clay rich loess soil is found to be suitable for traditional rammed earth structures [5]. Traditional rammed earth construction has also taken place in the alluvial plains in China [6]. However, for a specific technique one might not be able find ideal soils that can satisfy code requirements and stabilization may be required [10]. Also, to avoid unnecessary use of stabilizers and optimize associated costs, soil evaluation and selection is essential [1].

Currently, earthen building construction in Pakistan is mostly carried out by those who cannot afford conventional industrial building materials. The construction type is mostly adobe, cob or wattle and daub, which is carried out in available soils without material evaluation [11]. Rammed earth is not a common practice in Pakistan. However, the world's tallest stabilized rammed earth building, the headquarters of Telenor, has been recently constructed in Pakistan by foreign consultants SIREWALL [12].

Approaches for evaluation of soils for earth building construction vary from qualitative field tests, to quantitative soil and product laboratory tests. The approach in which products produced from soils are tested for strength, durability and shrinkage is followed in the New Zealand Standards and USA building codes.

[13], [14]. The New Zealand standards are considered comprehensive and have been referenced in developing standards and guidelines by others such as ASTM E2392/E2392M − 10 Standard Guide for Design of Earthen Wall Building Systems as well [13][15].

In order to develop local knowledge and expertise, the soil samples from Peshawar, that are used in other techniques as well, are studied for rammed earth application by following the tests specified for rammed earth in the New Zealand Code NZS 4298:1998.

2 MATERIALS AND TESTING

2.1 Materials

To investigate the potential of un-stabilized rammed earth building construction, using in-situ available soils for Peshawar, soil samples were collected from five random locations. Soils from same places are also being used for other earthen building techniques. Table 1 shows the detail of the sources and the USCS classification of the soil. These sample were collected after removing the topsoil, from depths 3 feet and below.

Table 1- Location, coordinates and USCS classification of soil samples

Sample	**Location**	**ISRIC Coordinates (Longitude,Latitude)**	**USCS Class**
S1	Fields Palosai Maqdarzai	71.49, 34.04	CL (Lean Clay)
S2	Bilal Abad Gulshan Rehman Colony Kohat Road	71.57, 33.98	Cl (Lean Clay)
S3	Start of Zone 3 Regi Model town, near to Nasir Bagh Road	71.43, 34.03	CL-ML with gravel
S4	Shaheen Housing Society, Warsak Road Peshawar	71.47, 34.09	ML (Silt)
S5	Mattay Asshab Baba	71.48, 34.14	ML (Silt)

2.2 Experimental Work

NZS 4298:1998 requires testing the strength, durability and shrinkage for soil evaluation for rammed earth technique. The on-site moisture handful drop test was used to set the moisture content of the soil specimens. The compressive strength was tested using the UTM machine. The impact of a droplet and rain was investigated in the durability tests. The wet dry appraisal test, tested the behavior of the specimens after exposing them to six under water cycles. The shrinkage was observed using linear shrinkage box method. The investigations carried out and the procedures followed in this study have been listed in Table 2.

Table 2- Tests carried out on collected soil samples

Property	**Procedure in Appendix Clause of NZS 4298:1998** [16]
Compression Test	A5
Wet-Dry Appraisal Test	C
Durability Test	D and E
Shrinkage	F
On-Site moisture handful drop test	G

2.3 Specimen Preparation

For the uniaxial unconfined compressive strength tests, three rammed earth samples were produced from each soil. The rammed earth samples were compacted into cylindrical molds with a height (400 mm) to diameter (200 mm) ratio of 2 as shown in figure 1a. The applied compactive effort comprised ramming with a 4.5 kg and 4 in diameter rammer, with a fall of 1.5 feet. The samples were compacted in three layers and each layer received 26 blows.

a. b. c.

Figure 1: Rammed earth test specimens, a. for compression test, b. for durability and wet dry appraisal test, and c. compression test being carried out in universal testing machine (UTM)

For the durability and wet dry appraisal tests, rectangular prismatic samples with 300 ×125 ×125 mm dimensions were produced as shown in figure 1b. To achieve the same compactive effort for these dimensions, the same rammer was used but the soil was compacted in 5 layers with each layer receiving 50 blows.

The compactive effort was calculated using equation (i) below:

$$Compactive\ Effort = \left(\frac{\left(\frac{Blows}{layer}\right) \times No.\ of\ Layers \times Weight\ of\ hammer \times Height\ of\ Fall}{Volume}\right) \quad \text{(i)}$$

For consistency, all the samples were produced at the same compactive effort and OMC as given in Table 3.

Table 3 – Compactive effort applied in rammed earth samples vs standard proctor and modified proctor

	Cylinder	**Blocks**	**Standard Proctor***	**Modified Proctor***
Blows	26	50	25	25
No. of layers	3	5	3	5
Weight of rammer (kg)	4.5	4.5	2.5	4.5
Height of Fall (mm)	305	450	450	450
Volume (m^3)	0.0016	0.0049	0.0009	0.0009
Compactive Effort ($kN.m/m^3$ approx).	985	989	600	2700

*For maximum particle size less than 3/8in or 19mm

The rammed earth samples have been cured in accordance with section 2.1.11.1of the NZS 4298:1998 for 28 days in average daily temperature of 13^o

3 RESULTS AND DISCUSSION

The strength and durability tests have been performed for rammed earth in accordance with *NZS 4298:1998 Materials and Workmanship for Earth Buildings.*

3.1 Uniaxial Unconfined compressive strength:

The uniaxial unconfined compressive strengths for rammed earth samples in accordance with appendix A of NZS 4298:1998 are presented in Table 4. According to the passing criteria, the lowest strength in compression should be greater than 1.14 N/mm^2 (165 psi) for a height to width ratio of 2. The moisture content for all the samples was set according to appendix G of NZS 4298:1998. Figure 1c shows the typical splitting crack in compression test under progress. The properties of investigated soils samples in Table 4 were found to be unsuitable for rammed earth construction. For rammed earth application, the compressive strength could be upgraded, by improving the gradation of the soil mix, increasing the compactive effort or reducing the rammer diameter and by chemical stabilization.

Table 4- Compressive Strength of rammed earth samples

Sample	**Unconfined Compressive Strength**	**Result according to passing criteria**
S1	2 samples had 92.8-93.50 psi 1 sample had 120 psi Average 102.33 psi	Fail
S2	65.1±10 psi	Fail
S3	70.1±12.5 psi	Fail
S4	59.7±6.1 psi	Fail
S5	25.4±5 psi	Fail

3.2 Durability Test using Geelong Drip Test:

The Geelong Drip test has been performed in accordance with the appendix E of NZS 4298:1998 rammed earth samples of size 300×125×125 mm. If the pit depth is equal or greater than 15 mm and the moisture penetration is 120 mm or greater or the erodibility index is greater than or equal to 5, the sample is considered to have failed the durability test. The moisture content for all the samples was set according to appendix G of NZS 4298:1998. The details of durability tests result, for rammed earth samples, have been provided in Table 6 below.

Table 5- Durability of rammed earth samples using Geelong Drip Test

Sample	**Pitting Depth (mm)**	**Erodibility Index**	**Depth of moisture penetration (mm)**	**Result according to passing criteria**
S1	5	3	10 Pass	Pass
S2	3.5	2	7.5 Pass	Pass
S3	5	3	20 Pass	Pass
S4	1.5	2	10 Pass	Pass
S5	0	2	24 Pass	Pass

3.3 Durability Test using Spray Erosion Test:

The test has been performed in accordance with the appendix D of NZS 4298:1998 rammed earth samples of size 300 × 125 × 125 mm. If the pit depth is equal or greater than 120 mm and the moisture penetration is 120 mm or greater and the erodibility index is greater or equal to 5, the soil sample is considered to have failed the durability test. The moisture content for all the samples was set according to appendix G of NZS 4298:1998. A post-test condition of a sample is shown in figure 2a. The details of spray erosion test results, for all types of samples, have been provided in Table 6.

Figure 2a: Post-test condition of specimens, a. after spray erosion test, and b. linear shrinkage box test

Table 6- Durability of rammed earth samples using Spray Erosion Test

Sample	Pitting Depth	Erodibility Index	Depth of moisture penetration (mm)	Result according to passing criteria
S1	45	2	Pass	Pass
S2	102	4	Pass	Pass
S3	≥120/hr	5	Fail	Fail
S4	45	2	Pass	Pass
S5	≥120/hr	5	Fail	Fail

3.4 Comparison between Geelong Drip and Bulletin 5 Spray Erosion Test Results:

All un-stabilized rammed earth samples passed the Geelong drip test which is a less aggressive test based on simulating the impact of a droplet. The S3 and S5 (Regi Model Town and Asshab Baba Mattay) samples failed the spray erosion test which is a more aggressive test based on simulating the impact of rainfall. The S2 (Kohat Road) sample also performed poorly in the spray erosion test. However, the S1 and S4 (Palosai Maqdarzai and Shaheen Housing Society) samples performed well in the spray erosion test. Hence, it is possible to pass one durability test and fail the other.

3.5 Wet Dry Appraisal Test:

The test has been performed in accordance with the Appendix C of NZS 4298:1998 on rammed earth samples of size 300 × 125 × 125 mm. and the results have been provided in Table 7. The moisture content for all the samples was set according to appendix G of NZS 4298:1998. The samples were soaked for 2 minutes under 10 mm of water over three coins as spacer for 6 cycles and matched among the eight criteria in section C3.4 of NZS 4298:1998 as follows:

a. Crazing type Crack pattern
b. Star type Crack pattern
c. Local Swelling
d. Local pitting in at least 5 locations
e. Local or general fretting, that is loss of layers of soil either upon wetting or drying
f. Penetration of water, as indicated visually on the outer surface**s** of the brick, by more than 70% of the brick width
g. The loss of fragments of the brick larger than 50mm greatest dimension, except that part of the fragments which come from with 50mm from the edges of the brick shall not be included h. Efflorescence

Table 7- Wet dry appraisal test results of rammed earth samples

Sample	No. of Failed Criteria	Result according to passing criteria
S1	4	Fail
S2	4	Fail
S3	3	Fail
S4	2	Fail

S5	1	Fail

Criteria f and h was not satisfied for all RE samples. With respect to criterion g, there was no loss of fragments greater than 50 mm excluding the edges of the sample. However, the layers of the RE sample in case of the S2 (Kohat Road) sample separated. Star type and crazing type crack pattern, local swelling, local pitting and the loss of thin surficial layer locally or generally was observed in most of the samples. Although, all the samples failed till the completion of the sixth cycle, the samples made from Asshab Baba Mattay soil (S5) failed only one criterion from the above list.

3.6 Linear Shrinkage Test:

This test was carried out in accordance with Appendix F of NZS 4298. Smooth surface molds of 600 × 50 × 50 mm dimensions were lubricated with oil as shown in figure 2b. Moistened sieved soil passing the moisture content drop test prepared for the RE samples is placed and rammed in three layers and air dried for 28 days in the indoor environment at average daily temperature of 13^{o}C. The results of linear shrinkage box test for each sample is provided in Table 8 as under.

Table-8: Linear Shrinkage Test Results

Sample	Measured Shrinkage at 28 Days in mm	Linear Shrinkage %	Result according to passing criteria
S1	12	2	Fail
S2	8.5	1.42	Fail
S3	5.75	0.96	Fail
S4	4	0.67	Fail
S5	0	0	Pass

According to Table 2.1 of NZS 4298:1998, samples with linear shrinkage ≤0.05% are suitable for rammed earth construction. Hairline crack of less than or equal to 0.3 mm may be acceptable for the above-mentioned sample size in order to pass the criteria provided by the standard. Except for S5 (Asshab Baba Mattay soil) sample all other soil samples fail this criterion.

3.7 Summary of Results:

The summary of strength and durability tests for un-stabilized rammed earth applications is provided in table 9 below.

Table-9: Summary of Test Results

Sample Location	Compression Test	Durability Tests		Wet Dry Appraisal Test	Linear Shrinkage Test
		Geelong Drip	Spray Erosion Test		
S1	Fail	Pass	Pass	Fail	Fail
S2	Fail	Pass	Pass	Fail	Fail
S3	Fail	Pass	Fail	Fail	Fail
S4	Fail	Pass	Pass	Fail	Fail
S5	Fail	Pass	Fail	Fail	Pass

4 CONCLUSIONS AND FURTHER STUDIES

Pakistan lacks studies data and codes for rammed earth application. The aim of this study was to investigate the in-situ soils in their natural state for their potential of un-stabilized rammed earth. The conclusions drawn from this study are that in-situ soils from the selected locations in Peshawar are not suitable, in their current natural state, for rammed earth application. The soil sample in general passed one or two tests but not the overall tests required by NZS 4298:1998, prior for determining their suitability for rammed earth applications. This study provides baseline data for the silty-clayey in-situ soils in Peshawar for rammed earth application. The soils that failed the required criteria may be made suitable by either altering the gradation of the soil mix, increasing the compactive effort with respect to the tamper, reducing the rammer diameter, using green stabilizers or by varying moisture content. Further experimentation can be carried out in accordance with the recently superseded (20202) version of NZS 4298.

REFERENCES

[1] H. Houben and H. Guillaud, *Earth Construction A comprehensive guide*. 1994.
[2] M. Moquin, "Ancient Solutions for Future Sustainability: Building with Adobe, Rammed Earth, and Mud," pp. 543–552, 1994.
[3] Auroville Earth Institute, "Traditional Rammed Earth." [Online]. Available: http://www.earthauroville.com/traditional_rammed_earth_en.php.
[4] Auroville Earth Institute, "Modern Rammed earth." [Online]. Available: http://www.earthauroville.com/modern_rammed_earth_en.php.
[5] H. Schroeder, *Sustainable Building with Earth*. 2015.
[6] P. A. Jaquin, C. E. Augarde, and C. M. Gerrard, "A chronological description of the spatial development of rammed earth techniques," 2008.
[7] SIREWALL, "Sirewall Inspiration Kit," 2018.
[8] J. C. Morel, A. Mesbah, M. Oggero, and P. Walker, "Building houses with local materials: Means to drastically reduce the environmental impact of construction," *Build. Environ.*, vol. 36, no. 10, pp. 1119– 1126, 2001.
[9] V. Maniatidis and P. Walker, "A Review of Rammed Earth Construction," no. May, 2003.
[10] B. Windstorm and A. Schmidt, "A Report of Contemporary Rammed Earth Construction and Research in North America," *Sustain.*, vol. 5, no. 2, pp. 400–416, 2013.
[11] S. H. Lodi, A. J. Sangi, and A. Abdullah, "Adobe Houses (Pakistan)," 2012.
[12] SIREWALL, "SIREWALL News," 2018. [Online]. Available: https://sirewall.com/new-tallest-rammedearth-structure-on-earth-we-broke-our-old-record/.
[13] B. King, "Review of Earthen Building Codes and Standards from Around the World," pp. 1–32, 2006.
[14] M. C. J. Delgado and I. C. Guerrero, "The selection of soils for un-stabilized earth building: A normative review The selection of soils for un-stabilized earth building: A normative review," *Constr. Build. Mater. Elsevier*, 2007.
[15] ASTM, *ASTM E2392/E2392M − 10 Standard Guide for Design of Earthen Wall Building Systems*. 2014, pp. 1–10.
[16] Standards New Zealand, *NZS 4298: 1998 Materials and workmanship for earth buildings*. 1998.

CONSEQUENCES OF POORLY COMPACTED BACKFILL MATERIAL ON CONCRETE RETAINING WALLS

[a] Qazi U. Farooq, and [b] Muhammad Tayyab Naqash,
a: Department of Civil Engineering, Islamic University of Madinah, Saudi Arabia, qaziumar@gmail.com; umar@iu.edu.sa
b: Department of Civil Engineering, Islamic University of Madinah, Saudi Arabia,, engr.tayyabnaqash@gmail.com

Abstract- Reinforced concrete retaining walls are extensively used in civic and transport infrastructure. Their integrity plays an important role in ensuring public safety. Despite the advancement in construction techniques and improvement in design codes, retaining wall failures are still common and instigating life and property loss. The quality of backfill material is directly related to the distresses generated in the wall. The classical design techniques used for earth pressure estimation normally consider triangular earth pressure distribution and ignores the soil arching effects. In this research prevalent finite element analysis has been done on concrete retaining walls with different backfill characteristics. Overall 12 cases has been investigated to highlight the consequences of poorly compacted backfill material on concrete retaining walls. This multi-physics approach considers the real effect of the backfill soil on pre-failure distresses generated in the concrete retaining walls. It has been observed that poorly compact backfill material can generate higher stresses in wall at critical sections. The analysis results can be effectively utilized to improve the wall geometric designs and hence, enhance the public safety and furthermore, believed to be helpful for the engineers involve in the design and construction of retaining walls.

Keywords- Concrete retaining walls, Backfill material, Horizontal thrust, Wall stresses.

1 INTRODUCTION

Reinforced Concrete (RC) retaining walls are an essential element of the contemporary infrastructure. They are used to support potentially vulnerable slopes, deep excavations, embankments and basements. Over the years the design and construction of RC retaining walls is greatly improved and many innovative technologies have been adopted. However, retaining wall failure is still a common phenomenon. A 6.1 meter retaining wall failed in 2012 in western India due to poorly selected backfilled properties [1] Several retaining walls collapsed during 2004 Niigata ken earthquake in Japan causing partial blockade of the road network[2]. In May 2006 a concrete retaining wall with a height of 8.9-m failed in Kahramanmaras, Turkey, damaging several buildings. Investigations revealed that, the poor material quality was one of the main failure cause.[3] The poor compaction reduces the stabilizing forces in the wall system, and have high active forces. The back fill material characteristics plays a very vital role in wall stability and any miscalculation and error can lead to a human disaster. Classical wall design practices are still considering linear (triangular) earth pressure distribution for the backfill material and ignoring the soil arching effect. The initial methods to estimate soil arching action were partly based on Rankine theory and later proved inaccurate. The modern studies shows two stage development of arching effect. These findings demonstrates higher lateral earth pressures than classical theory. Moreover, the pressure distribution is nonlinear approximately centered at a height 2/5 times the height of the wall [4]. Utilizing full scale experimental test results and mathematical techniques, the modified earth pressure equations for lateral active forces considering arching effect were also developed. Similar to classical methods, the stress friction angle(Ø) of the soil and the wall friction (δ) angle are the key input parameters for these equations[5].

Because of the non-linear pressure distribution and heterogeneity in the backfill material, FEM analysis can be a very effective tools for the earth pressure estimation in retaining walls. A number of studies have been found in the literature about the application of FEM on earth pressure analysis. For example, finite element modelling was applied to deep excavation analysis for metro station excavation and was found in good comparison with instrument readings[6]. Simplified 2D FEM studies using PLAXIS was conducted on deep excavation and tunneling in soft ground. The study was focused on the effects of mesh, ground conditions and the constitutive soil models. The soil conditions were selected form real field investigation results. The accurate prediction of ground movements was found to be difficult and dependent on parametric selection[7].

Whilst, the earth pressure estimation has been thoroughly studied, the existing literature regarding, retaining rigid walls and backfill characteristics mainly focus on development of lateral pressures and wall instability (movement), the effect of backfill quality on pre-failure distresses developed at the various sections of wall has not been well understood. The peak stresses and strains present along the wall geometry during the life span of the structure, are required to be highlighted for the identification of the critical sections. The Multiphysics FEM analysis has been presented in this study to highlight functional distresses generated by poorly compacted granular backfill material on concrete retaining walls.

2 METHODOLOGY

Backfill material compaction sometimes become challenging due to space requirements. The numerical modeling and simulation technique using Finite Element Method has been designated in this study, to present the effects of inappropriate compaction of backfill material on the reinforced concrete retaining walls. The study cases are designed on the basis of backfill material, having different degree of compaction and external horizontal loading (Thrust). Three soil compaction levels are selected for the modeling. The compaction level varies in terms for relative density ranging from very loose to medium. Each compaction case is then subjected to four different loading conditions. The load is applied as external horizontal thrust. Consequently, overall 12 cases are analyzed, the classification of the studied cases is shown in Table 1.

Table43: Studied Cases Based on Back Fill Compaction and External Loading

Backfill Compaction	**External Horizontal Thrust**			
	10-kPa	**50-kPa**	**100-kPa**	**200-kPa**
Very Loose	Case 1-A	Case 1-B	Case 1-C	Case 1-D
Loose	Case 2-A	Case 2-B	Case 2-C	Case 2-D
Loose to Medium	Case 3-A	Case 3-B	Case 3-C	Case 3-D

3 MODEL AND MATERIALS

The 2-D Finite Element Modeling (FEM) using COMSOL Multiphysics software has been used in this study [8].As compared to the classical geotechnical FEM modules, the COMSOL is capable of analyzing coupled Multiphysics phenomena simultaneously. The structural mechanics module (used in the analysis) of the software, provide freedom to the researchers to designate any material as linear elastic, nonlinear elastic and elastoplastic. The wall system has been characterized by a 3.5-m high tapered reinforced concrete retaining wall. The base width of the wall stem is 1-m, while the crown is 0.5-m wide. The wall foundation is 3-m wide, with a thickness of 0.5-m. The wall is supported on dense granular natural ground. The ground depth of 3-m below foundation is considered in this study (i.e. equal to foundation width). The main area of interest "loose backfill material" is presented by a 3.0 x 3.5 m rectangular block. The geometric details of the wall model system is shown in Figure 1. The load required to be supported is applied on the right corner of the backfill material. The top of the backfill and wall crown were kept free, hence no surcharge load was considered.

Since the main wall is model as reinforced concrete, typical strength and deformation properties of RC are adopted. The concrete density (ρ) is taken as 2300 kg/m^3, and 28 days compressive strength value of 28-MPa is considered. The value of Elastic modulus (E) and poisons ratio (ν) for concrete are assumed to be 25-GPa and 0.20 respectively.

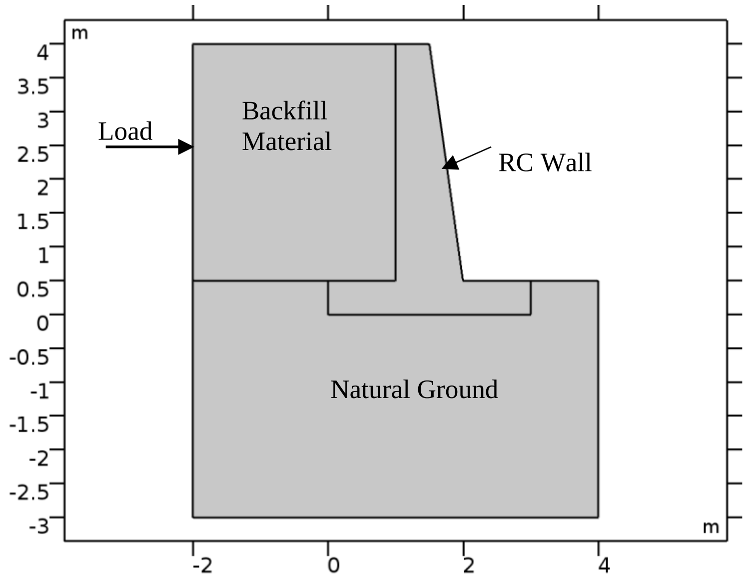


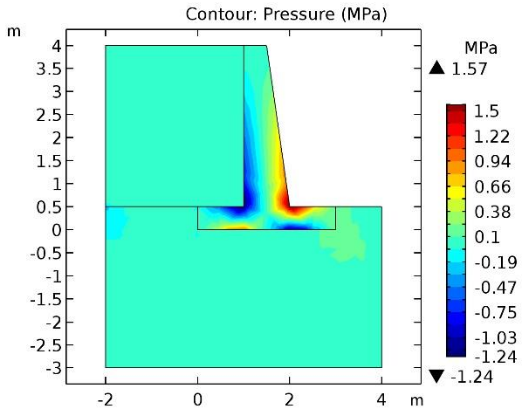
Figure 9: Model Geometry of a Tapered RC Retaining Wall

The foundation supporting natural ground is modeled as dense sand, whereas, the backfill material is represented by three different compaction levels of loose sand. The density of the sand varies from 1400 to 1600 kg/m$^{3.}$ The particulars of the mechanical properties of the geo-material and concrete used in the FEM analysis is presented in Table 2.

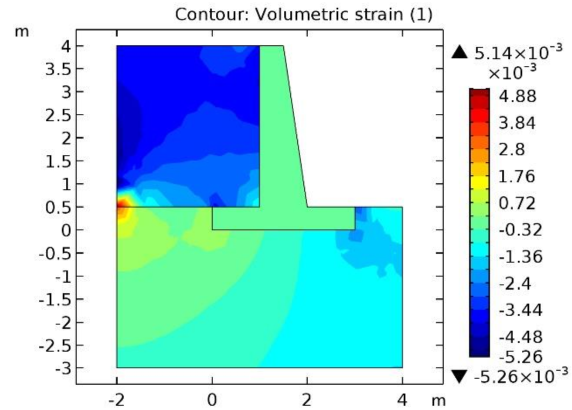
Table 44 Material Properties Used in the Study

Material		**Density (ρ) kg/m^3**	**Elastic Modulus (E) MPa**	**Poisson ratio (ν)**	**Material Specific Parameter(s)**
Wall Concrete		2300	25000	0.20	Compressive Strength (fc') = 28 MPa
Natural Ground		1700	80	0.30	Frication Angle (ϕ) = 38^o
Backfill Material	**Very Loose**	1400	15	0.30	Frication Angle (ϕ) = 30^o
	Loose	1500	35	0.30	Frication Angle (ϕ) = 32.5^o
	Loose to Medium	1600	70	0.30	Frication Angle (ϕ) = 35^o

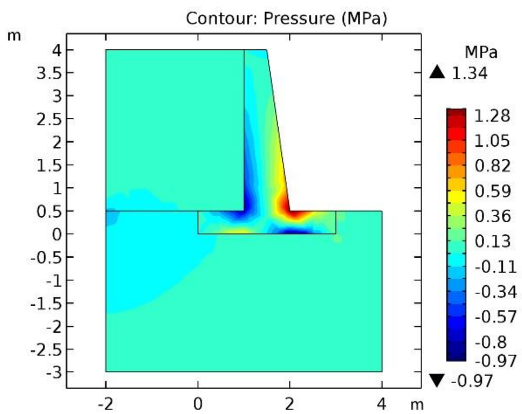
4 RESULTS AND DISCUSSIONS



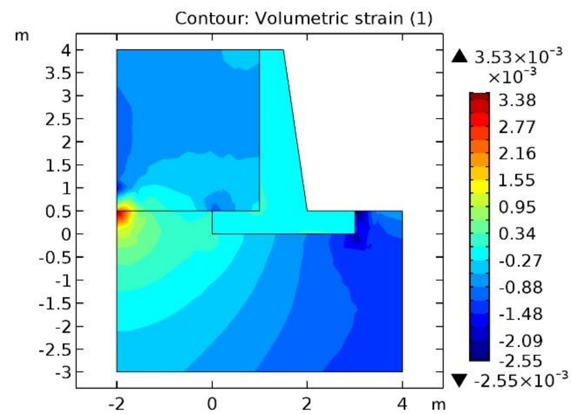
***10(a)** Stress Distribution for Case 1C*



***2(b)** Volumetric Strain for Case 1C*



***2(c)** Stress Distribution for Case 3C*



***2(d)** Volumetric Strain for Case 3C*

Figure 2: Examples of FEM Analysis Results at 100kPa Horizontal Thrust

The key objective of this study is to locate the pre failure distresses in the wall, owing to improper compaction of the backfill material. Therefore, FEM analysis has been carried out at low strain levels. The materials and the overall wall system remains within elastic limit. The analysis results for Case 1C (very loose backfill soil at 100 kPa Horizontal Thrust) and 3C (loose to medium backfill soil at 100 kPa Horizontal Thrust) are shown in Figure 2. Form Figure 2(a) and Figure 2(c) it is clear that most of the stresses in the system are taken by the wall. Under the same external loading and boundary conditions, the very loose backfill material implies 15% more peak stress, in the wall as compared to the medium backfill material. The location of the peak stress remains the same i.e. at the exterior joint of the wall base and stem[8].

The deformation results of the system for the above two cases are shown by Figure 2(b) and Figure 2(d). The very loose granular backfill material deform more than the medium loose material. Since concrete is more rigid than the soil, therefore in both cases almost no deformation is observed in the wall. The location of peak volumetric strain is at the junction of backfill material and the natural ground at the loading side. This may be a limit of FEM model and the real semi-infinite ground may have well distributed strains over the larger area with minimal effects. The peak volumetric strain **(ε_{vol})** for Case 1C is found to be 5.14 x10^{-3}, and for Case 3C it is 3.53 x 10^{-3}.

The peak wall stresses collected form all the 12 cases are plotted are Figure 3. The backfill material in the loosest state always impose higher stresses on the wall as compared to the other two compaction levels. With the increase in applied horizontal thrust this trend further diversified. These results are in good comparison with the experimental study on Ottawa sand carried out at the University of Washington, based on these experiments, the soil densification decreases the magnitudes of active stresses behind rigid walls.[9] The higher deformations in the loose back fill material may cause cracking which lead to the moisture penetration in case of a rainfall event and can impose a serious threat to the wall safety.

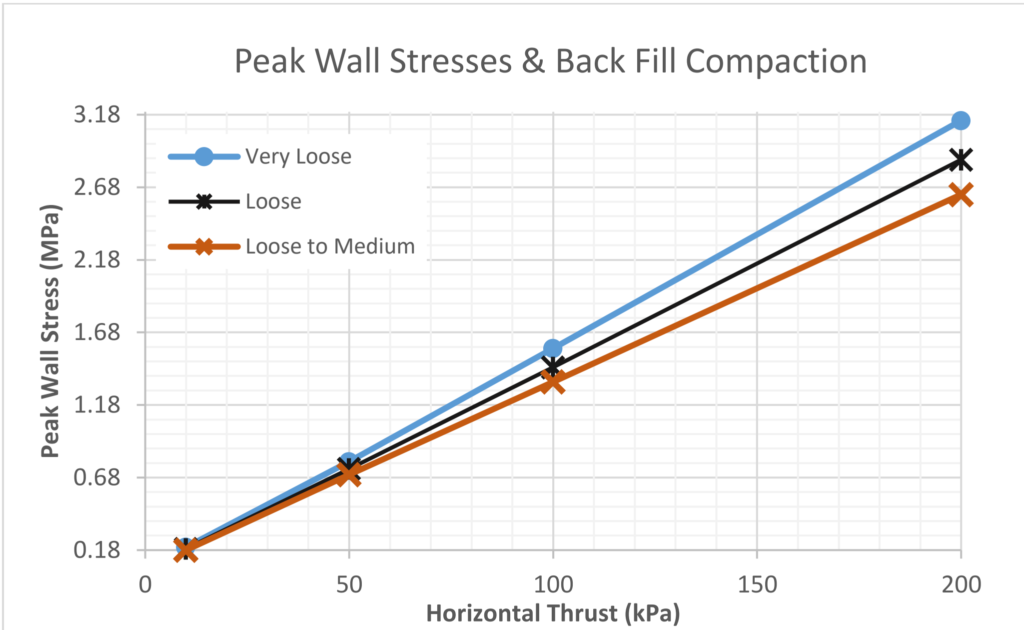


Figure 3: Effect of Backfill Material Quality on the Wall Stresses

5 CONCLUSIONS

COMSOL Multiphysics based FEM analysis conducted on dozen of retaining wall cases reveals that, improperly compacted backfill material imposes higher stresses in the RC retaining walls as compared to the well compacted material. The peak stresses (pre failure) developed on the joint between the wall stem and its base. Therefore, Stem-base joint should be carefully designed. Loose backfill material is further vulnerable in cases where external loading is relatively high.

Most of the stresses in the system are engaged by the wall. However, volumetric deformations development in the backfill material and foundation supporting strata. These deformations may lead to cracking, allowing water infiltration and can effect the overall wall safety. Despite of space issues, the backfill material should be properly compacted for RC shear walls of raft and other shallow foundations to avoid moisture induced settlements.

6 RECOMMENDATIONS

Compaction characteristics of a Backfill martial, plays a significant role in determining wall stability. In case, there is a space limitation, to deploy a mechanical compaction technique. The well-graded, self-compacting course grain geo-material, such as 60-40 grave-sand mixture should be used. If properly dumped the material can gain up to 98% of relative density.

ACKNOWLEDGEMENT

The authors acknowledge the Deanship of Research, The Islamic University of Madinah, Kingdom of Saudi Arabia, for their financial support, through research project No 86/40.

REFERENCES

[1] S. V Abhishek and V. Tarachand, "Case Study of Failure of Retaining Wall At Dwarakanagar , Visakhapatnam," in Pro**ceedings of Indian Geotechnical Conference Roorkee, 2013, no. December, pp. 1–4.**
[2] M. Okamura, "Damage To Masonry Retaining Walls During Niigataken-Chuetsu Earthquake," in *Sixth International Conference on Case Histories In Geotechnical Engineering Arlington VA*, 2008, no. August, pp. 1–

7.
[3] Temiz, Huseyin & Kayadelen, Cafer & Kaplan, Hasan & Muhammed, Yasin & Durgun, Muhammed. (2010). Retaining Wall Failure due to Poor Construction and Design Aspects A Case Study. Electronic Journal of ConstructionTechnologies Electronic Journal of Construction Technologies. 6. 46-6146.
[4] R. L. Handy, "The arch in soil arching," *Journal of Geotechnical Engineering*, vol. 111, no. 3, pp. 302–318, 1985.
[5] K. H. Paik and R. Salgado, "Estimation of active earth pressure against rigid retaining walls considering arching effects," *Geotechnique*, vol. 53, no. 7, pp. 643–653, 2003.
[6] C. Chheng and S. Likitlersuang, "Underground excavation behaviour in Bangkok using three-dimensional finite element method," *Computers and Geotechnics*, 2018.
[7] S. Likitlersuang, C. Surarak, D. Wanatowski, and A. S. Balasubramaniam, "Analysis Of Ground Movements Induced By Mrt Construction: A Case Study Of Bangkok Mrt Blue Line Project," 2013.
[8] COMSOL, "Introduction to COMSOL Multiphysics 5.3," *Manual*, 2014.
[9] M. A. Sherif, Y. Fang, and R. I. Sherif, "KA and Ko Behind Rotating and Non-Yielding Walls," *Journal of Geotechnical Engineering*, vol. 110, no. 1, pp. 41–56, Jan. 1984.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

EFFECT OF SAWDUST- LIME AND SAWDUST ASH-LIME ON THE GEOTECHNICAL PROPERTIES OF AN EXPANSIVE CLAYEY SOIL

[a] Abbas Khan, [b] Omar Hamdi Jasim, [c] Daanyal Umar
a: Civil Engineering Department, CECOS university of IT & emerging sciences Peshawar, abbas@cecos.edu.pk
b: Civil Engineering Department, Yildiz Technical University, Istanbul, Turkey, ojasim37@gmail.com
c: Civil Engineering Department, CECOS university of IT & emerging sciences Peshawar, , danyalomer@cecos.edu.pk

Abstract- When the applied loads on the soil is higher than its capacity, the engineers resort to certain methods to stabilize the soil by improving its load carrying capacity against the externally applied loads. The utilization of natural materials to improve engineering parameters of soil have become very popular in recent years; they are environmentally friendly materials and are available cheap. In this research, expansive clay is treated with a mixture of sawdust (SD) with Lime (L) and sawdust ash (SDA) with lime (L). Atterberg limits, unconfined compression, and permeability tests were conducted to study the effects of the additives in the soil. It was concluded from the tests that the sawdust – lime and sawdust ash – lime mixtures decreased the consistency limits of the clay. Also, an improvement was noticed in the unconfined compressive strength and coefficient of permeability of the stabilized soil. Also, optimum dosages of sawdust – lime and sawdust ash – lime of 3% and 4% respectively were found to give the best results.

Keywords- Consistency Limits, Expansive Clay, Lime, Sawdust, Sawdust Ash, Permeability, Unconfined Compressive Strength

1 INTRODUCTION

The expansive nature of clay usually makes it unsuitable to be used as a bed for roads, foundations for buildings etc. They are treated and stabilized so that their geotechnical properties could be enhanced before application of load. Using mineral addition in the soil is a very common method to improve the engineering properties of soil. Sometimes the added materials are considered expensive or harmful to the environment. There are many approaches to improve the geotechnical properties of soil such as grouting, adding lime and addition of natural and synthetic fibers. However, the recent trend follows the use of cheap and environmentally friendly materials to improve the geotechnical performance of the clay. The effects of the additives on geotechnical properties of soil are investigated by conducting different tests such as liquid limit, plastic limit, unconfined compression test, permeability, consolidation test etc.

One of the methods of the recent trend to improve the engineering properties of soil is mixing sawdust (SD) and sawdust ash (SDA) with lime (L) in clayey soil. Sawdust is a material that is produced from tree cutting and can also be produced in different ways such as woodworking and others. It can be extracted in different shapes and sizes depending on the mechanism of cutting. Johnson and Gopinath [1] used marble dust and coir fibers to enhance the engineering properties of expansive clay and revealed that the addition of the blend helped in reducing the swelling pressure of clay. Abdi, et al. [2] also studied the reduced swelling of the soil by using polypropylene fibers. Jasim and Cetin [3] Akinwumi, et al. [4] investigated the effects of sawdust in clayey soil. It was concluded that the use of sawdust decreased liquid limit and plastic limit of the clay. Many researches have been conducted on the addition of the natural fibers into the soil and their study reported positive impacts on the shear strength of clay [3, 5, 6]. Also, these studies outlined an optimum dosage of sawdust of about 3% of the dry weight of the soil on the immediate shear strength [3, 4]. It was also found that the optimum sawdust content decreased from 3 % to 2 % in the long term tests on the same clay used by [3]. In another study, the compressibility behaviour of natural additives in soil was investigated on Cochin marine clays (CH) with inclusion of randomly distributed coir fibers (extracted from coconut). This study concluded that the compressibility of reinforced clay is lower than that of unreinforced clay. It was also concluded that compression index values decreased with increase in coir fiber content. On the other hand coefficient of consolidation increased with increasing coir fiber content [7]. Another cheap, ecofriendly and acceptable stabilizing agent for improving the geotechnical properties of soil for the use of foundation is Sawdust ash (SDA) [8]. It was reported in a study that the liquid limits and the plasticity index decreased, and the shear strength parameters considerably increased after using SDA [9]. Ikeagwuani [10] investigated the characteristics of black cotton soil upon addition of mixture of SDA and lime. A mixture of 6% SDA and 4% lime by weight of the black cotton soil was added in the soil. The results showed decrease in the liquid limit and increase in the plastic limit. In conjunction to these results another study also revealed same behaviour [11]. Lime stabilization is considered globally as of the most effective methods to improve the geotechnical properties of cohesive soil [12]. The basic idea behind the lime addition is that limited addition of lime for soils generally improve their properties for construction purposes. Bell [13] modified fat clay by quick lime and concluded that the optimum moisture content of remodeled clay increases nonlinearly with increasing added content of quick lime. Also, it was noticed that the maximum dry density reduces with increasing quick lime content. In addition to this, the liquid limit and plasticity index of the remodeled clay was found to reduce with increase in the content of quick lime and time, but its plastic limit was found to increase with increasing mix-ratio of quick lime and time. Harichane, et al. [14] and Jasim [15] studied the effects of addition of lime, natural pozzolana and a blend of the two on the soil. Lime and natural pozzolana were added to these soils at ranges of 0-8% and 0-20% respectively. In the same study, blend of lime and natural pozzolana were also added in the similar ranges. The results presented significant improvement in cohesion and internal friction angle with curing period and particularly at later ages for each single soil. Similar behavior was reported by the addition of silica fume [16] and lime [17].

Keeping all the literature above into consideration, the aim of this research paper is to study the effects of sawdust- lime and sawdust ash-lime mixtures on clayey soil. Effects of SD-L and SDA-L have been studied on the consistency limits, unconfined shear strength, coefficient of permeability of expansive clay. Also, the optimum dosages of SD-L and SDA-L for improving the geotechnical properties of expansive clayey soil have been presented in this paper.

2 EXPERIMENTAL PROCEDURES

2.1 *Materials used:*

a. *The soil*

The soil used was brought from the city of Istanbul. It was located 5 meters below the surface. The colour of the soil used is brown. The basic laboratory procedures were conducted on the soil for classification. Table 1 presents the properties of soil whereas Figure 1 presents the grain size distribution of soil.

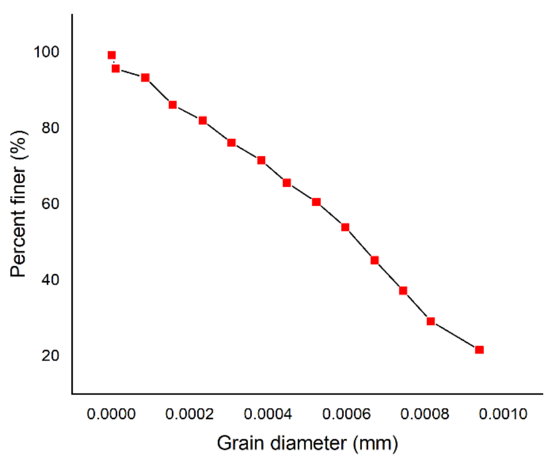


Figure 1: Grain size distribution of the silty clay soil

Table 1: Properties of the soil

LL (%)	PL (%)	PI (%)	Gs	Silt (%)	Clay (%)	USCS
63	30	33	2.64	69	31	CH

b. Sawdust (SD)

The sawdust used for soil improvement was brought from a wood factory. The specific gravity test was conducted on it and was estimated to be 1.37. The water content in the sawdust was 15.33% at the instant of mixing. The grain size distribution and the used sawdust is illustrated in Figure 2 and Figure 3.

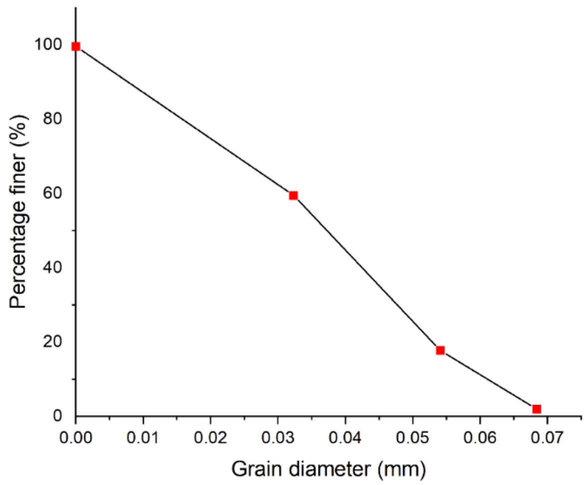


Figure 2: Grain size distribution of the sawdust

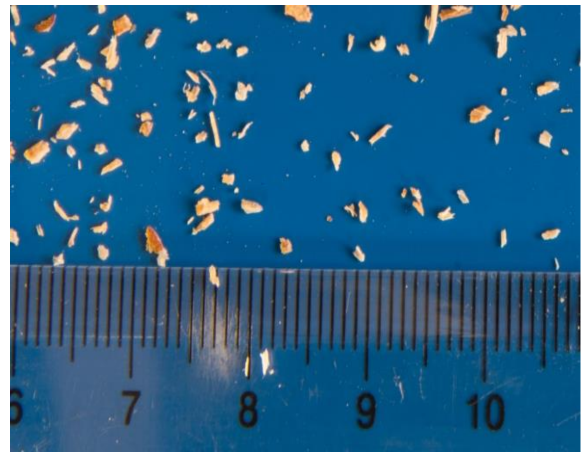


Figure 3: Used sawdust

c. Sawdust Ash (SDA)

The sawdust ash used for soil stabilization was prepared by burning the sawdust obtained from the wood factory in an oven at 500 ^{o}C for two hours to make sure that all of the sawdust was converted into sawdust ash.

d. Lime (L)

There are several types of lime quicklime, slaked lime and hydrated lime. The lime used in this study was hydrated lime with PH of 12.52. A 5kg bag of lime was purchased locally for this study.

e. Experimental Program

In order to find the maximum dry density (MDD) and optimum moisture content of soil, compaction tests were performed on the specimens according to ASTM D698-07. The Atterberg limits (Liquid limit and Plastic limit) were found according to ASTM D4318 and ASTM 4318, 15. The specific gravity of soil was also determined according to ASTM D 854-0. The unconfined compression strengths of stabilized and unstabilized soils were found according to ASTM D2166/ ASTM D2166M-13. The permeability test is based on ASTM D 5084.

3 RESEARCH METHODOLOGY

3.1 Compaction test on soil

The method given in the ASTM D698-07 using the standard compaction test was applied to determine the maximum dry density and the optimum moisture content of the soil sample. An optimum water content of 28% while maximum dry unit weight of 13.7 (kN/m^3) was reported on the completion of test.

3.2 Sample Preparation

The samples were prepared by drying the soil sample in an oven for 24 hours at 105^{o}C. The additives (Sawdust- Lime and Sawdust Ash-Lime Mixtures) were added to the dry soil. The effects of the additives were investigated on five different percentages ranging between (1-5) percent by the dry weight of the soil. Each ratio consisted of half portion of the first mineral addition and the remaining half the other. For example, for 1% of the (SD-L) additive used, 0.5% SD and 0.5% L by dry weight of the soil were added to the soil. The mixing was done manually under ideal circumstances to obtain a homogeneous mixture followed by the addition of water. After compaction of samples, they were extruded by inserting oiled Shelby tubes. The extruded samples were covered with thin polyethylene nylon and kept in the desiccator to maintain the required water content for an hour and then they were tested. However, the Atterberg limit samples were tested directly.

4 RESULTS

4.1 *Atterberg Limits Tests*

Liquid limit and plastic limits tests were conducted in order to identify the immediate effect of SDL and SDL-A on the consistency limits of the clay. From Figure 4 and Figure 5 it is clear that the liquid limit and the plastic limit decreases as the mixture content increases, the same behaviour was confirmed by [3, 13, 15, 18]. According to Bell [13], generally adding lime to the clay causes immediate effect on the plasticity because of increasing the calcium content in the soil. The particles experience flocculation and are lumped. The sawdust is considered as cohesionless material and causes decrease in the consistency limits of the soil. It reduces the fine content of the soil [3, 15]. The sawdust ash also works as a cohesionless materials and it tends to reduce the plasticity of the clay. It was reported that on adding SD-L and SDA-L up to 5 % reduced the liquid limit by (12.6 %, 12.3 %) respectively. The plastic limit results also decreased by (5.69 %, 8.33%) respectively for both of the mixtures.

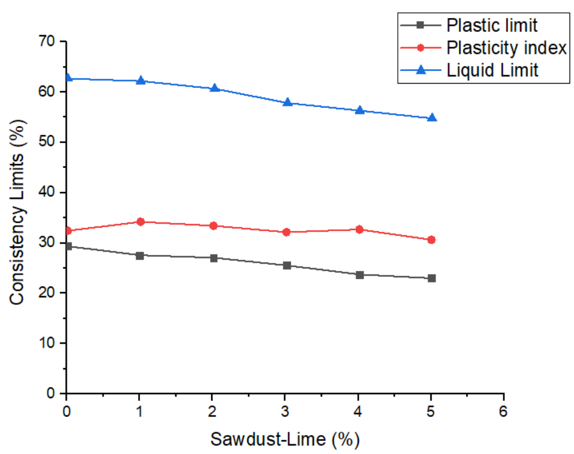


Figure 4: Effect of SD-L content on consistency limits

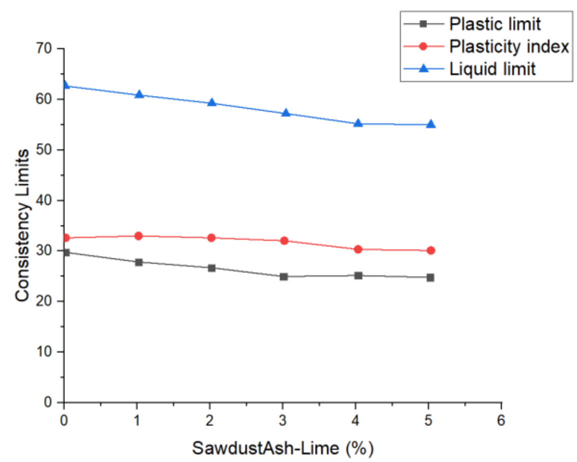


Figure 5: Effect of SDA-L content on consistency limits

4.2 *Unconfined Compressive Strength*

The unconfined shear test was performed on the raw soil as well as the treated soil. It was reported that the addition of sawdust ash lime and the sawdust lime enhanced the shear strength of the clayey soil [3, 13, 15, 18]. Adding SDL up to 5 % increased the shear strength by (21.4 %) as compared to the raw soil (0% SDL). However, 3% of SD-L was found to be the optimum content for the soil in terms of improving its shear strength, see Figure 8. On the other hand, on adding 5% of SDA-L content to the soil, an improvement of 59% was reported as compared to that of the raw soil (0% SDA-L). However, 4% content of SDA-L was found to be the optimum content for soil in terms of improving its shear strength, see Figure 9.

The gain in strength is because of the chemical reactions taking place between the admixtures and soil minerals. On adding mixture of lime and sawdust/sawdust ash in soil two types of reaction takes place. Lime possess cementing properties and the hydration reaction takes place immediately as the mixture is added into the soil. The sawdust ash on the other hand, are responsible for the pozzolanic reaction and contributes in strength of soil at the later ages. Overall, the results reflect a positive impact on the improvement of unconfined compression strength of clayey soil. The effects of sawdust-lime and sawdust ash lime on the unconfined compressive strength for stabilized soil samples are shown in Figure 6 and Figure 7.

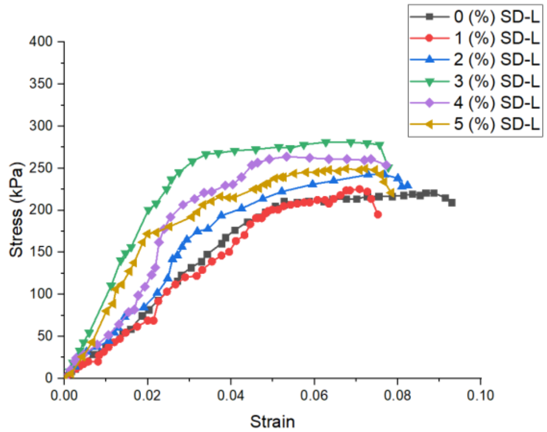


Figure 6: stress strain relationship for soil SD-L

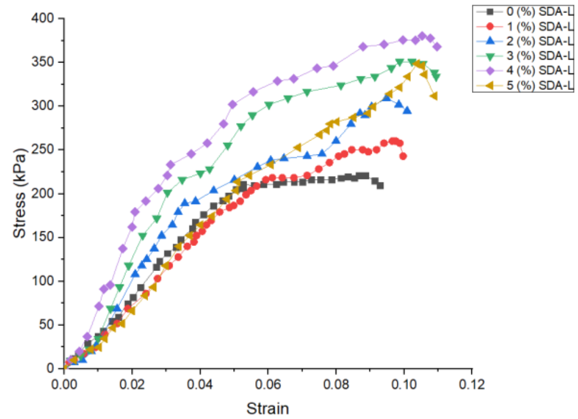


Figure 7: stress strain relationship for soil SDA-L

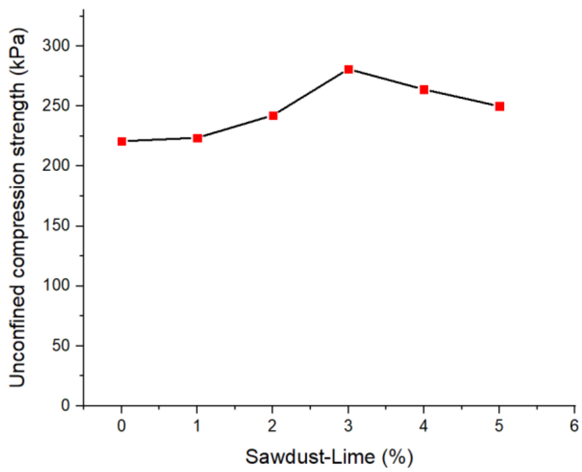


Figure 8: Unconfined compression strength of at various percentages of SD-L

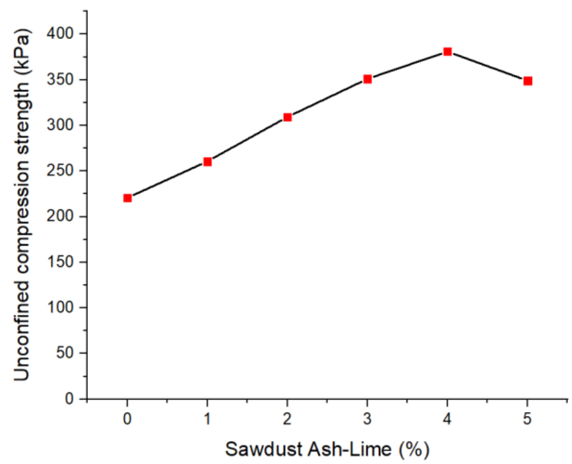


Figure 9: Unconfined compression strength of at various percentages of SD-L

4.3 Permeability test

A comparison of the hydraulic conductivity was conducted between the unstablized specimens and the specimens stabilized with mixture of SD-L and SDA-L. The coefficient of permeability of the specimens stabilized with mixture of SD-L and SDA-L was relatively more than that of the unstabilized specimens. The coefficient of permeability increased with increase in the contents of SD-L and SDA-L as shown in Figure 10. The increase in the permeability with the contents of these mixtures is due to the added materials (SD and SDA) acting as barrier between the fusion of clay particles thus increasing its permeability. Also, formation of gel due to hydration and pozzolanic reaction is another reason contributing to the increase in permeability. The moisture from the clay is utilized in the formation of gel which gives rise to capillary voids (the voids previously filled by water are replacedwith air) and as a result the coefficient of permeability increases.

A remarkable difference in the rate of increase of permeability at higher and lower doses than the optimum dose can be seen in Figure 10. The reason to this difference can be attributed to the excess sawdust particles present above the optimum dose. The clay-clay particle cohesion is reduced due to more sawdust accumulating in-between the soil particles thus forcing the soil matrix to change and as a result greater rate in the increase of permeability is recorded at the contents of both the mixtures above the optimum dose. On the other hand, at lower doses the sawdust particle being low in quantity do not significantly reduces the cohesion between clayey particles thus not forcing the soil matrix to change and as a result low rate of increase in permeability is recorded at the lower doses.

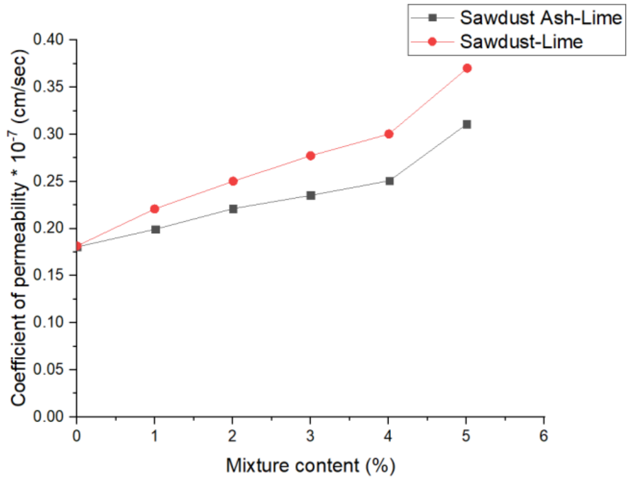


Figure 10: Effect of sawdust lime and sawdust ash lime on permeability.

5 CONCLUSIONS

Following conclusions can be derived from the conducted study:

- The consistency limits of the clay decreased with increasing percentages of sawdust – lime and sawdust ash – lime. The reason is that sawdust acts as a non-cohesive material between clay particles and thus reduces the fusion of clay particles resulting in decreased consistency limits.
- Unconfined compressive strength of clay improved remarkably with increasing content of sawdust – lime and sawdust ash – lime mixtures. This is because of hydration and pozzolanic reactions taking place as a result of addition of sawdust, sawdust ash and lime.
- The permeability coefficient increased as the ratio of the added mixture increased. The reason for the increase is due to the particles of sawdust and sawdust ash preventing the cohesion between the soil and the formation of the supplementary cementitious products leaving voids behind and thus increasing the permeability coefficient.
- Based on the unconfined compressive strength results of the stabilized soil, the optimum dosages of sawdust – lime and sawdust ash – lime was reported to be 3% and 4% respectively.

REFERENCE

[1] S. Johnson and B. Gopinath, "A Study on the Swell Behaviour of Expansive Clays Reinforced with Saw Dust, Coir Pith & Marble Dust," IJERT, 5, 565, vol. 570, 2016.
[2] M. R. Abdi, a. Parsapazhouh, and m. Arjmand, "Effects of random fiber inclusion on consolicdation, hydraulic conductivity, swelling, shrinkage limit and desiccation cracking of clays," 2008.
[3] O. H. Jasim and D. Cetin, "Effect of sawdust usage on the shear strength behavior of clayey silt soil," Sigma, vol. 34, no. 1, pp. 31-41, 2016.
[4] I. Akinwumi, O. Ojuri, A. Ogbiye, and C. Booth, "Engineering properties of tropical clay and bentonite modified with sawdust," Acta Geotechnica Slovenica, vol. 14, no. 2, 2017.
[5] K. E. Etim, C. C. Ikeagwuani, E. E. Ambrose, and I. C. Attah, "Influence of Sawdust Disposal on the Geotechnical Properties of Soil."
[6] S. Sun, B. Liu, and T. Wang, "Improvement of Expansive Soil Properties Using Sawdust," The Journal of Solid Waste Technology and Management, vol. 44, no. 1, pp. 78-85, 2018.

[7] R. K. Kar, P. K. Pradhan, and A. Naik, "Consolidation characteristics of fiber reinforced cohesive soil," Electronic Journal of Geotechnical Engineering, vol. 17, pp. 3861-3874, 2012.
[8] H. Karim, M. Al-Recaby, and M. Nsaif, "Stabilization of soft clayey soils with sawdust ashes," in MATEC Web of Conferences, 2018, vol. 162: EDP Sciences, p. 01006.
[9] S. Khan and H. Khan, "Improvement of mechanical properties by waste sawdust ash addition into soil," Jordan Journal of Civil Engineering, vol. 10, no. 1, 2016.
[10] C. Ikeagwuani, "Compressibility characteristics of black cotton soil admixed with sawdust ash and lime," Nigerian Journal of Technology, vol. 35, no. 4, pp. 718-725, 2016.
[11] H. Owamah, E. Atikpo, O. Oluwatuyi, and A. Oluwatomisin, "Geotechnical properties of clayey soil stabilized with cement-sawdust ash for highway construction," Journal of Applied Sciences and Environmental Management, vol. 21, no. 7, pp. 1378-1381, 2017.
[12] S. T. Noor and R. Uddin, "Effect of Lime Stabilization on the Alteration of Engineering Properties of Cohesive Soil," in Global Civil Engineering Conference, 2017: Springer, pp. 1257-1264.
[13] F. Bell, "Lime stabilization of clay minerals and soils," Engineering geology, vol. 42, no. 4, pp. 223-237, 1996.
[14] K. Harichane, M. Ghrici, and S. Kenai, "Effect of curing time on shear strength of cohesive soils stabilized with combination of lime and natural pozzolana," 2011.
[15] O. H. Jasim, "The effect of the usage of sawdust and quicklime on shear strength behaviour of clayey silt soil," 2016.
[16] M. Türköz, H. Savaş, and G. Tasci, "The effect of silica fume and lime on geotechnical properties of a clay soil showing both swelling and dispersive features," Arabian Journal of Geosciences, vol. 11, no. 23, p. 735, 2018.
[17] K. Saranya and M. Muttharam, "Consolidation stress effect on strength of lime stabilized soil," Journal of Engineering Research and Applications, vol. 3, no. 5, pp. 1515-1519, 2013.
[18] T. H. T. Ogunribido, "Geotechnical properties of saw dust ash stabilized southwestern Nigeria lateritic soils," Environmental Research, Engineering and Management, vol. 60, no. 2, pp. 29-33, 2012.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

EFFECTIVENESS OF STONE DUST AS AN EXPANSIVE SOIL STABILIZER

[a] Muhammad Bilal, [b] Dr. Naveed Ahmad
a: Student, Department of Civil Engineering, University of Engineering and Technology Taxila Pakistan.
Email: mbilal6249@gmail.com
b: Assistant Professor, Department of Civil Engineering, University of Engineering and Technology Taxila Pakistan Email: naveed.ahmad@uettaxila.edu.pk

Abstract- This paper mainly deals with the laboratory investigation of waste stone dust to improve problematic expansive soils that shrink and swell during wet and dry season. The expansive soils result in shrink /swell and differential settlement of structures. Soil survey conducted in Sudan reveals the fact that almost one third of Sudan's 2,600,000 km^2 area is occupied with the expansive soil[1]. Usage of certain kind of admixtures on expansive soil looks prepossessing on the works where other improvement techniques become extensive and therefore are expensive too. So, to maintain a balance in between the source budget and project efficiency and ultimately to avoid problem of disposing available soil, and borrowing the soil, betterment in problematic soil through admixtures looks appealing. Therefore, an experimental examination was conducted on the soil by blending the soil with SD (Stone Dust) to study impact of stone dust on soil properties. The percentage of stone residue was taken within range of 5% to 20% of the total soil sample in tests. The primary arrangement of tests incorporates specific gravity, liquid limit, plastic limit, CBR, Optimum moisture content and maximum dry density were performed on soil and same tests were directed in the second arrangement on the soil sample blended with stone dust. Laboratory examinations states that soil swell potential was diminished to 4.4% from 8.4% at 12% SD and soil transformed to non-expansiveness from medium expansiveness similarly plastic index and liquid limit values were found to be gradually decreasing from 20.1% to 8.4% and 40.7% to 31.9% respectively at 0% to 18% SD, moreover the values of OMC reduced from 12.4% to 6.2% and MDD improved from 1.84 (g/cm3) to 2.16 (g/cm3) at 0% to 20% SD, likewise the void ratio and porosity improved from 0.632 to 0.637 and 38.74% 38.89% respectively at 0% to 18% SD.

Keywords- Soil Stabilization, Expansive Soil, Stone Dust.

1 INTRODUCTION

The growth of urbanization and industrialization leads to more structural development and roads infrastructure and ultimately they demand for good soil conditions to be used as the strong foundations, but expansive soils are more problematic for construction purposes and are generally available to a large extent in various regions of the world, including Argentina, Zimbabwe, China, Mexico Cuba, Ethiopia, India, Iran, Japan, Morocco, Spain, United States of America, Ghana, Myanmar, Australia, Oman, Saudi Arabia, South Africa, Sudan, Turkey, Canada, Venezuela, Israel and Brazil**.**[2] Traditional ways to deal with such type of soil were to replace the available problematic soil, that appeared to be more complicated because of high costs as well as due to the environmental reasons. In Sudan damage due to expansive soil exceeds $6,000,000 (that is almost 8,000,000 Sudanese pounds) annually[1]. Expansive soil absorbs moisture from surroundings and the backfill soil oversaturates that causes the shrinkage and swelling phenomenon in soil due to which it exerts elevated pressure on the walls of foundations and cracks are produced in the walls and ultimately differential settlement of structure takes place and finally the failures occurs. Expansive soil occurs in such areas where annual evapotranspiration and evaporation is more than precipitation and geotechnical reports by various agencies state that expansive soil occurs in Dera Ismail Khan, Khairpur (Sind) and Chakwal [3] while current investigations is upon Chakri soil. The ground improvement results in reduction in soil compressibility and enhancement in its shear strength which in turns play an important role in improving soil bearing capacity, slope stability and earth retaining structure like coffer dams and retaining walls etc. [2] Methods primarily opted for ground improvement include Biological, Physical and Chemical which improve the soil engineering properties. Biological soil stabilization is done by planting and it is suitable for the soil that is exposed to wind and water. Chemical stabilization is done in a way that the chemicals are mixed in water and sprinkled over the problematic soil to increase compaction and to act like binders. Physical stabilization includes drainage and compaction. A few other mechanical ways to improve poor soils are pre wetting, soil replacement water content control, imposing surcharge and other natural or man-made fiber additions like jute and geotextiles[4]. Solid waste Stone Dust is easily accessible in Pakistan from Sargodha, Margalla, Barnalla and Mangla crushers. SD utilized in current investigation is the solid waste of stone crushing industry of Margalla, and was taken in laboratory testing by dry weight of soil from 0% to 20%, and blended into the soil to inspect the impact of blending on various geotechnical properties of soil like OMC, Plastic Limit, MDD, Liquid Limit, Specific Gravity and CBR properties of soil. In the past researches although the trends obtained from different researchers are somehow similar to this investigation but optimum values are different because of difference in geotechnical properties of locally available soil of different areas. This shows that there is a need of increasing data bank by using problematic soils present in different parts of the world to understand the possible variations in optimum ranges.

2 LITERATURE REVIEW

The improvement of soil by addition of different admixtures has been carried out by different researchers. But less statistics have been published on the geotechnical properties of soil that is reinforced by Waste Stone Dust (WSP). [4] Conducted the standard compaction test, Atterberg's limit tests and California bearing ratio test by adding with the blend of stone dust and lime in percentage of 6% and 1%, respectively in the soil sample and study revealed the fact that CBR value of soil was improved up to 26%. Moreover, Stone dust addition to week soil increases the shrinkage limit, angle of internal friction, maximum dry density and decreases the Atterberg limits, soil cohesion and optimum moisture content.[5] Performed various tests including compaction test, plasticity test and strength tests by adding different percentages of stone powder on the soil that was basically gravelly in nature and he came to know that by mixing soil with stone dust, CBR value was increased and plasticity was decreased and soil was able to meet the specifications of morth as sub base material only by addition of stone dust up to 25-35%. [6] carried out the tests like liquid limit, plastic limit, unconfined compressive test, California bearing ratio, and standard compaction test on soil by blending lime and waste stone powder mix as an admixture and found remarkable results. For CBR test 1% lime plus 6% stone powder and for UCS 7% lime and 6% stone powder have shown distinctive effect on strength properties. [7] Introduced the experimental test results of the examination of impact of fly ash and stone dust blending in various percentages and by the addition of 20%-30% of admixture, controlled the swell index of expansive soil and marked improvements in various properties of soil, and inferred that blend of stone dust and fly ash is more efficient than fly ash and stone dust alone in soil reinforcement. [8] Led arrangement of tests and inferred that increase in proportion of quarry dust diminishes Optimum moisture content (OMC),Atterberg's limit values and cohesion while improves the properties like Angle of internal friction and Maximum dry density of shrink/swell soil.[9] Performed various tests to examine impact of quarry dust gathered from Madepalli, India, on mud compaction properties and replaced the soil with quarry dust in extents of 10,20,30,40 and 50%and inferred that solitary 30% of quarry dust utilized as an admixture in soil is adequate to improve its properties and to make it suitable for development.[10] Shear quality test, consistency test and compaction tests were performed on gravelly soil by addition of stone residue in the scope of (20%-30%) and it uncovered the fact that maximum dry density increased from (3%-7%) and California Bearing Ratio value improved from (16%-52%) and soil meet the (MoRTH) specifications. The addition of 20% stone dust in expansive soil uncovered the way that MDD and CBR value improved by 5% and 35% respectively, whereas optimum moisture content (OMC) and Atterberg limit values were diminished that made the soil suitable for the subgrade. Previous researchers have selected locally available problematic soils of their region. Although their trends are somehow similar but optimum values are different. This shows that there is a need of increasing data bank by using problematic soils present in different parts of the world to understand the possible variations in optimum ranges.

3 RESEARCH METHODOLOGY

3.1 *Material Collection*

a. *Expansive Soil*

Black cotton soil, shrink/swell soil or Expansive soil is present in abundance in Pakistan. The primary reason of its occurrence is the chemical decomposition of rocks, for example, Basalt and by phenomenon of igneous rocks erosion.

These type of soils are rich in Iron, Magnesia, Alumina and Lime while suffering in the Phosphorous, organic contents and Nitrogen [7]. The soil for this study is collected from Chakri, Rawalpindi, Pakistan. The soil is expansive having good shear strength in dry form but becomes very soft, weak and swells when comes in contact in water and drastically decreases when comes in contact with moisture content. Untreated soil properties are listed in table-1.

Table -45 Properties of Soil without adding Admixture

Sr. No	Test Names	Standard	Value Obtained
1	Liquid Limit	ASTM D 4318	40.7%
2	Plastic Limit	ASTM D4318	20.7%
3	Plastic Index	ASTM D4318	20.1%
4	Grain Size Analysis	ASTM D-6913	96% fines
5	Moisture Content (%)	ASTM D 2216	22.17
6	Specific Gravity	ASTM D854	2.695
7	Optimum Moisture Content (%)	ASTM D698	12.4
8	Maximum Dry Density (g/cm3)	ASTM D698	1.84
9	Swelling Potential	ASTM D 1883	8.4%
10	Void Ratio	$e = (G.\rho_w/\rho_d) - 1$	0.632
11	Porosity	$n = (e / (1+e)) * 100$	38.74%

b. Stone Dust

Stone dust is a waste material produced in stone pulverizing industry, and each crushing unit is evaluated to deliver 15-20% of stone dust.[11] It is the mechanical stabilizer and has high shear strength and enhances geotechnical properties of soil when mixed with it in suitable proportions. It stabilizes the problematic soils by improving its compaction characteristics and reducing the plasticity. Stone dust particles have angular shape therefore have good interlocking strength with soil and not only improves soil density but also reduces plasticity of highly plastic soils. [11]Moreover, stone dust possesses pozzolanic nature and contains coarse particles that is not observed in other admixtures like fly ash. The Stone dust used in current study was collected from the crushing plants working on Margalla hills, Taxila. The stone dust is taken by the dry weight of soil from 0% to 20%, and blended with soil to examine effect of mixing on properties of soil.

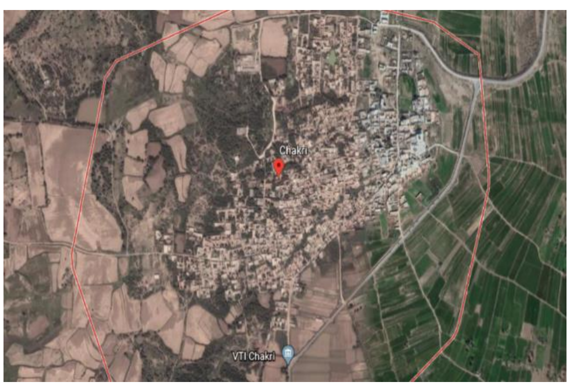


Figure 77-Chakri Soil Extraction Site

Figure 2-Margalla Quarry site

3.2 EXPERIMENTAL WORK

3.3 Sample Preparation

For mechanical soil stabilization, sample was set up in such a way that stone dust and soil were in dry state at mixing time, so, expansive soil sample and stone dust were placed into oven at 105 °C for 24 hrs. before mixing soil with the stabilizer. Stone dust was used in percentages of 5%, 12% and 18% of the dry mass of the soil sample to observe the soil behavior at even smaller percentages of SD to bring more efficiency in improvement as well as taking considerations of economicity. In this way, samples were prepared for the soil stabilization.

3.4 Experimental Program

Table-2 Sieve Analysis Results

Sieve #	4	10	20	40	60	100	200	
Diameter (mm)	4.75	2.00	0.85	0.425	0.25	0.15	0.075	Pan
Soil Retained (g)	0.40	3.90	1.30	0.00	1.90	0.60	0.40	191.5
Soil Retained (%)	0	2	1	0.00	1	0.3	0.2	96
Cumulative Passing (%)100	100	98	97	97	96	96.0	96.0	0

Preliminary tests, for example, soil gradation, liquid limit, plastic limit and specific gravity were performed followed by compaction test to acquire maximum dry density (MDD), OMC and finally strength tests like California Bearing Ratio and Direct Shear test were performed under soaked conditions. The same series of tests was repeated for soil mixed with different percentages of stone dust. Results of the soil testing before adding admixture are given in Table-1.

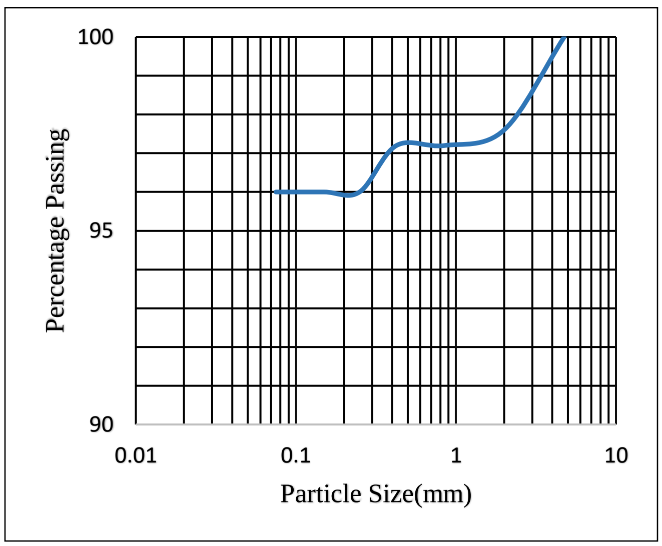


Figure-3 Soil Graduation Curve

3.5 Soil classification:

After performing the tests on soil, the soil is classified as CL (Lean Clay) according to USCS (Unified soil classification system) as shown in Table 3 and A-7-6 (clayey soil) according to AASHTO as shown in Table 4.

Table-3 Soil Classification according to USCS

Percentage Passing from Sieve #200	**96% which is >50% Then Fine grain soil**
Liquid Limit	40.7%
Plastic Limit	20.7%
PI= L.L-P. L	40.7- 20.7=20.1 %

P_{200}>50%---Fine grain Soil ~ P.I>7----Clay ~ L. L<50%	
Then Group of Soil	CL (Highly Plastic Clay)

Table-4 Soil Classification according to AASHTO

Percentage Passing from Sieve #200	**96% which is >36%**
Liquid Limit	40.7%
Plastic Limit	20.7%
PI = L.L-P. L	40.7-20.7 = 20.1 %
Then, Group of Soil	A-7-6 (clayey soil)

According to criteria defined by [12], soil used for this study is categorized as medium expansive.

4 RESULTS AND DISCUSSION

4.1 Effect of Stone Dust on Specific Gravity G_s

The untreated soil specific gravity was found to improve from 2.695 to 2.702 with increase in percentage of the stone dust (Fig-4).

4.2 Effect of Stone Dust on Void Ratio (e)

The void ratio of untreated soil sample was found to improve from 0.632 to 0.637 with increase in percentage of stone dust (Fig-5).

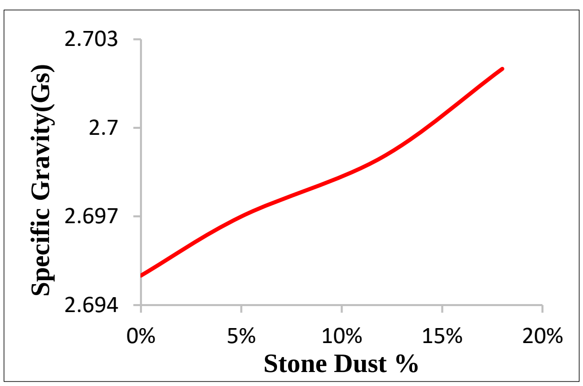


Figure 4-Effect of Stone Dust on Specific Gravity

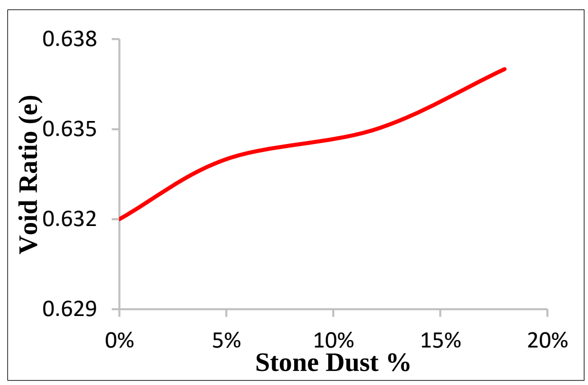


Figure 5-Effect of Stone Dust on Void Ratio

4.3 Effect of Stone Dust on Porosity (n)

Porosity of expansive soil was improved from 38.74% to 38.89% with increment in percentage of stone dust in (Fig-6).

4.4 Effect of Stone Dust on Liquid Limit (L.L)

Liquid limit estimation of expansive soil was found to diminish from 40.7% to 31.9% with increment in Stone Dust content (Fig-7).

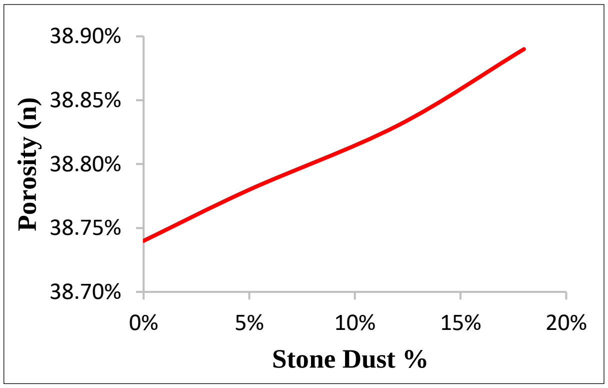


Figure 6-Effect of Stone Dust on Porosity

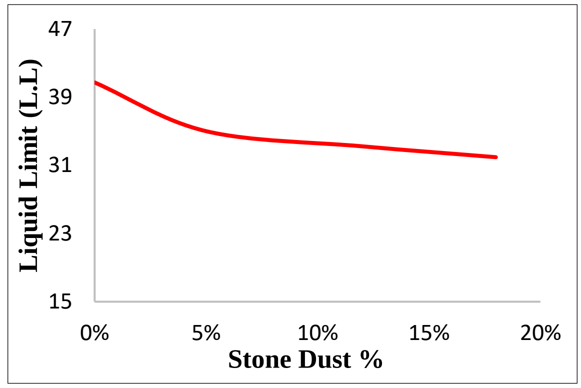


Figure 7-Effect of stone dust on liquid limit

4.5 Effect of Stone Dust on Plastic Limit (P.L)

The Plastic limit estimation of expansive soil was found to increase from 20.67% to 25% with increment in the percentage of Stone Dust. (Fig-8).

4.6 Effect of Stone Dust on Plastic Index (P.I)

The Plastic Index estimation of expansive soil was found to decrease from 20.064% to 8.4% with increment in percentage of Stone Dust (Fig-9).

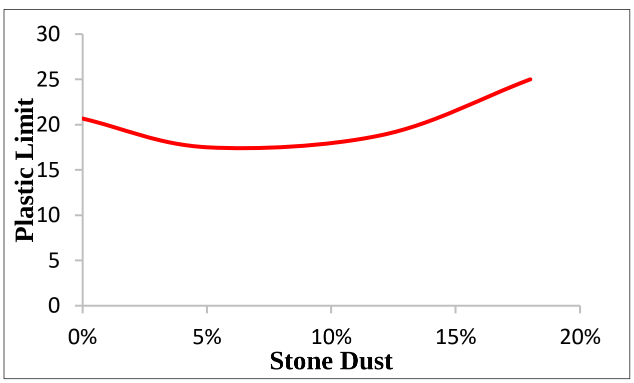


Figure 8-Effect of stone dust on plastic limit

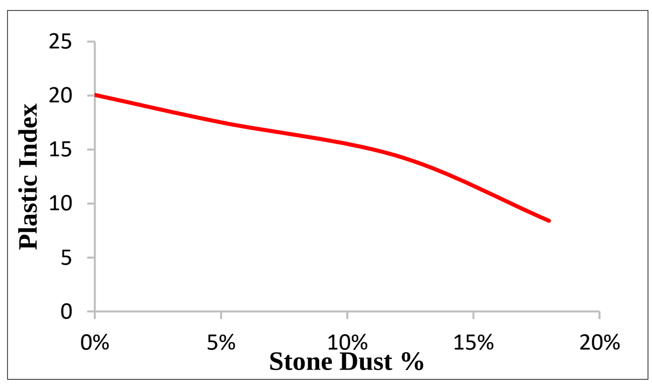


Figure 9-Effect of stone dust on plastic index

Table-5 Properties of Soil at different Admixture Percentages

S. No	Property	Value at 0%SD	Value at 5%SD	Value at 12%SD
1	Swelling (%)	8.4	6.56	4.43

Table-6 Swelling of Soil treated with SD

S. No	Property	Value at 5%SD	Value at 12%SD	Value at 18%SD
1	Specific Gravity	2.697	2.699	2.702
2	Liquid Limit	35.1%	33.2%	31.9%
3	Plastic Limit	17.5%	18.8%	25%
4	Plasticity Index	17.52%	14.4%	8.4%
5	Void Ratio(e)	0.634	0.635	0.637
6	Porosity (n) (%)	38.78%	38.83%	38.89%

Table-7 OMC and MDD of Soil treated with SD

S. No	Property	Value at 0%SD	Value at 10%SD	Value at 15%SD	Value at 20%SD
1	OMC (%)	12.4	11.76	9.16	6.2
2	MDD (g/cm3)	1.84	1.96	2.06	2.16

4.7 Effect of Stone Dust on OMC and MDD:

The MDD estimation of shrink/swell soil was found to be increasing from 1.84 (g/cm3) to 2.161 (g/cm3) with increment of Stone Dust. On the other hand, OMC of soil diminishes to 6.2% from 12.4% with increment in amount of Stone Dust. (Fig-10-12).

4.8 Effect of Stone Dust on CBR:

(Fig-13) shows that soaked CBR value of soil blended with different percentages of stone dust has decreasing pattern. The swelling of expansive soil decreases to 4.43% from 8.4% with increase in percentage of Stone Dust.

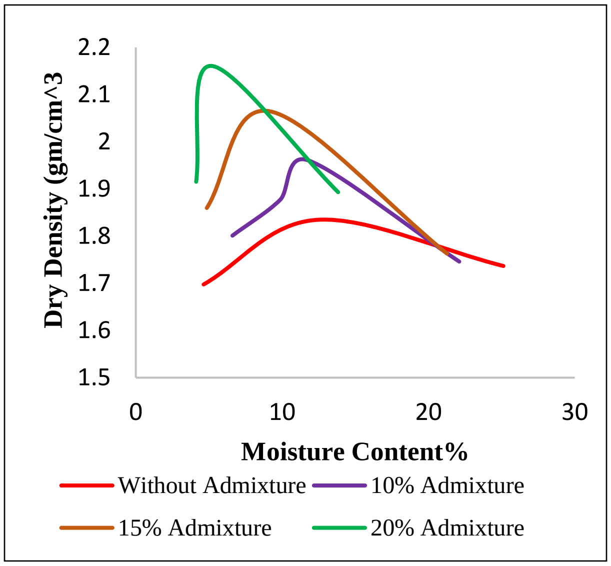


Figure 10-Compaction curve at variable SD percentage

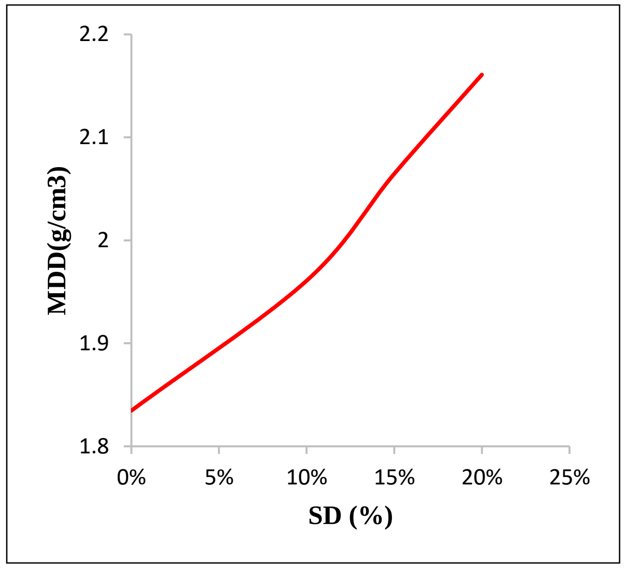


Figure 11-Effect of Stone Dust on Maximum Dry Density

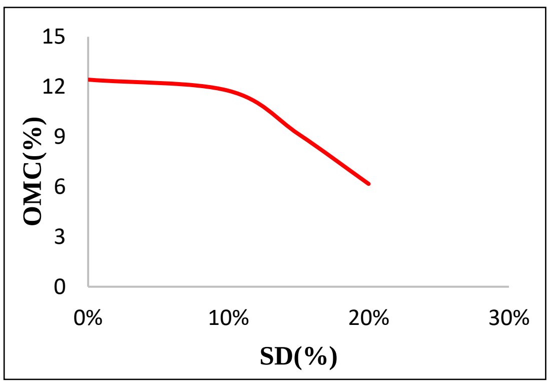


Figure 12-Effect of Stone Dust on optimum moisture content

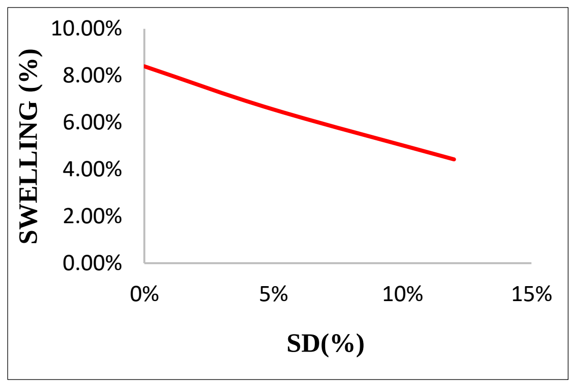


Figure 13-Effect of stone dust on soil swelling

So, it is clear from above experimental results that by increasing the amount of stone dust the value of specific gravity, plastic limit, void ratio, porosity and Maximum Dry density was increased and the properties like liquid limit, plasticity index, swelling potential and optimum moisture content were decreased as shown in Table (5-7). The soil swell potential reduced to 4.4% at 18% SD that lies in acceptable range and similar improvement was made when [9] used the quarry dust in range of 10,20,30,40 and 50% and concluded that only 30% was enough to improve soil properties. The reason why stone dust improves soil properties is that it possesses pozzolanic nature and contains coarse particles that improves compaction characteristics and reduces the plasticity. Moreover, it has good interlocking strength with soil because of its angular shape.

Research application in the construction industry is that the places like Dera Ismail Khan, Khairpur (Sind),Chakwal, Chakri and many more that are suffering from the problem of expansive soil can use the waste stone powder in improving the soil geotechnical properties instead of using the expansive material like cement and moreover they can get rid of fatigue of borrowing and disposing available soil.

Research significance is to provide guidelines and proper recommendations to be followed by locals during preconstruction period to avoid any post construction settlement problems in structures.

5 CONCLUSION

1. From the laboratory test results it is observed that initially the soil was medium expansive in nature but later at optimum percentage of 12% SD soil was transformed in to non-expansiveness.

2. The grain size analysis of soil clearly shows that the soil contains maximum quantity of fines almost 96% and initially the high value of plasticity index was observed that showed that the soil was highly plastic and cohesive in nature but later at optimum percentage of 18% SD plasticity of soil was reduced.
3. Optimum Moisture Content was found out to be decreasing gradually with increase in percentage of stone dust and reduced to 6.2% at 20% SD content which was beneficial in diminishing the amount of water required during compaction, and MDD was found to be gradually increasing from 1.84 to 2.16 and there was no optimum value but gradual increase in density with increase in SD.
4. The investigations uncover the fact that the liquid limit and plasticity index of the soil were reduced from 40.7% to 31.9% and 20.1% to 8.4% respectively and the plastic limit and specific gravity were improved from 20.7% to 25% and 2.695 to 2.702 at the optimum percentage of SD. So, SD can be considered best and economical soil reinforcing agent.

ACKNOWLEDGMENT

The author would like to thank the Department of Civil Engineering UET Taxila, that helped thorough out the research work, and special appreciation is given to my kind supervisor. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] Charlie, Wayne A., Mohamed A. Osman, and Elfatih M. Ali. "Construction on expansive soils in Sudan." Journal of Construction Engineering and Management 110, no. 3 (1984): 359-374.

[2] M. Chowdhury, "Shear Strength Properties of Compacted Expansive Soils University of Regina Faculty of Graduate Studies and Research," *Thesis*, 2013.

[3] "2190-Article Text-389-1-10-20180117.pdf." .

[4] S. Mishra, S. N. Sachdeva, and R. Manocha, "Subgrade Soil Stabilization Using Stone Dust and Coarse Aggregate: A Cost Effective Approach," *Int. J. Geosynth. Gr. Eng.*, vol. 5, no. 3, pp. 1–11, 2019, doi: 10.1007/s40891-019-0171-0.

[5] M. A. Ganie, Abhishek, and R. Sharma, "Soil Investigation and Effect of Stone Dust on Geotechnical," *Int. J. Inf. Mov.*, vol. 2, no. VII, pp. 73–80, 2017.

[6] A. Roohbakhshan and B. Kalantari, "Stabilization of Clayey Soil with Lime and Waste Stone Powder," *Int. J. Sci. Res. Knowl.*, vol. 1, no. 12, pp. 547–556, 2013, doi: 10.12983/ijsrk-2013-p547-556.

[7] M. S. Ali and S. S. Koranne, "Performance analysis of expansive soil treated with stone dust and fly ash," *Electron. J. Geotech. Eng.*, vol. 16 I, no. 1, pp. 913–982, 2011.

[8] A. K. Sabat, "A Study on Some Geotechnical Properties of Lime Stabilised Expansive Soil – Quarry Dust Mixes," vol. 1, no. 2, pp. 42–49, 2012.

[9] M. S. Dixit and K. A. Patil, "Utilization of stone dust to improve the properties of expansive soil," *Int. J. Civ. Eng. Technol.*, vol. 7, no. 4, pp. 440–447, 2016.

[10] P. V. V. Satyanarayana, "Performance of Crusher Dust in High Plastic Gravel Soils As Road Construction Material," *IOSR J. Mech. Civ. Eng.*, vol. 10, no. 3, pp. 01–05, 2013, doi: 10.9790/1684-1030105.

[11] Naman Agarwal, "Effect of Stone Dust On Some Geotechnical properties Of Soil," *IOSR J. Mech. Civ. Eng.*, vol. 12, no. 1, pp. 61–64, 2015, doi: 10.9790/1684-12116164.

[12] S. Asuri and P. Keshavamurthy, "Expansive Soil Characterisation: an Appraisal," *Ina. Lett.*, vol. 1, no. 1, pp. 29–33, 2016, doi: 10.1007/s41403-016-0001-9.

[13] ASTM, D. "Standard test methods for specific gravity of soil solids by water pycnometer." D854 (2010).

[14] ASTM, D. "Standard test methods for laboratory compaction characteristics of soil using standard effort." ASTM D698 (2012).

[15] ASTM D 6913. "Standard Test Method for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis."

Standard, A. S. T. M. "D2216-10. 2010." Standard test methods for laboratory determination of water (moisture) Content of Soil and Rock by Mass." West Conshohocken, PA: ASTM International (Accessed: 2014. http://www.astm. org/Standards/D6913. htm) (2010).

[16] ASTM D1883. "Standard test method for California bearing ratio (CBR) of laboratory-compacted soils." (2016): 1-5.

CHARACTERIZATION AND STANDARDIZATION OF SAND FOR LABORATORY TESTING IN PAKISTAN

[a] Engr. AllahDitta Kaleem, [b] Dr. Naveed Ahmad
a: MS Student-Civil Engineering Department, UET Taxila-Pakistan, adkaleem@gmail.com
b: Assistant Professor, Civil Engineering Department, UET Taxila-Pakistan, naveed.ahmad@uettaxila.edu.pk

Abstract- This study focuses on characterization and standardization of sand for geotechnical research in Pakistan. Sand samples were collected from two different locations inside Pakistan keeping in view annual mineral production reports of Mines and Mineral Department Government of Punjab. Samples were tested in different educational and commercial laboratories for determination of required properties. The tests carried out were color, specific gravity, grain size distribution, minimum dry density and maximum dry density, minimum void ratio and maximum void ratio, direct shear test, mineral composition, shape of grains and hydraulic conductivity. Results of samples were compared with Ottawa F-65 & F-50 standard sand in Illinois in United States of America in order to find out standard source of sand for geotechnical research in Pakistan. After comparing samples it was revealed that sand sample having identification D-KP collected from Khusab-Punjab Pakistan has more resemblance with Ottawa-sand therefore this source has been recommended as Standard Sand for Laboratory based Research activities in Pakistan.

Keywords- Ottawa Sand, Characterization Of Sand, Geotechnical Research, ASTM Specifications

1 INTRODUCTION

Sand is a granular material, which is composed of finely divided rock and mineral particles. It is defined by size being finer than gravel and coarser than silt. Unified Soil Classification System USCS defines sand as particles with a diameter of size between 0.074 millimeters to 4.75 millimeters. Generally Fine sand diameter ranges from 0.075mm to 0.425mm, medium sand diameter ranges from 0.425mm to 2.00mm and coarse sand diameter ranges from 2.00mm to 4.75mm. The chemical or mineral composition of sand varies, it depends on the local rock type or sources and conditions, but the most common ingredient of sand is Silicon Dioxide SiO_2. Sand sample collected from Khusab Punjab Pakistan having identification D-KP has 72.05% of Silicon dioxide constituent while Ottawa F-50 and Ottawa F-65 have greater than 99% of silicon dioxide as major constituent of chemical composition of sand.

In Pakistan sand is used in construction industries such as plastering walls, back fill material, road construction, water filtration plants, landscaping, grouting, concrete preparation, laboratories usage include field density test by sand replacement method, mortar test, concrete cube tests, cement test etc. World is moving towards construction of artificial islands whose one of major constituent is sand, moreover liquefaction potential is a hazard when any structure is supported above saturated sandy strata. Therefore, besides studying behavior of clay and silt it is very important to study different properties of sand. Very limited research has been carried out in Pakistan regarding characterization and standardization of sand sources. Many countries in the world have standardized local sources of sand for geotechnical research and other purposes such as Ottawa-Sand is standard source of sand for USA & Canada, Toyoura sand is standard source of sand in Japan and Quartzanium is the Indian standard sand as per IS-650, while no standard source of sand has been recommended in Pakistan. Lot of research work has been published regarding characterization and standardization of sand in different countries in recent past years. Such as Mohamed El Ghoraiby studied Physical and Mechanical Properties of Ottawa F-65 (USA) in 2020, Previous experimental studies were conducted for characterizing Ottawa F65 sand including cyclic triaxial as well as cyclic direct simple shear tests by (Bastidas 2016; Vasko 2015; Vasko et al. 2018) while Oluwapelumi O. Ojuri published research paper regarding Standard sand for geotechnical engineering and geoenvironmental

.

2 RESEARCH METHODOLOGY

2.1 *Source Identification*

There are different sources of sand in Pakistan, Natural sources of sand include Pit Sand, River Sand and Sea Sand while artificial source of sand is Manufactured Sand. After desk study and going through annual production reports of Mines and

Minerals Department Government of Punjab it was found that biggest sources of sand inside Pakistan are Mianwali and Khusab where 354,061 M.Tons and 79,750 M.Tons sand was produced for the months of July 2018 to June 2019 on the basis of royalty collection. Hence these two sources were selected for test study.

2.2 Sample

.40 kilograms of each sample was collected from both of these sites and Latitude and Longitude of sampling points were also recorded.

SERIAL NO.	LOCATION	SAMPLE ID	LATITUDE	LONGITUDE
1	Khusab-Punjab	D-KP	32°17'42.00"N	72°24'11.00"E
2	Mianwali-Punjab	F-MP	32°41'15.00"N	71°26'47.00"E

Fig.2.1 Sampling location in Khusab-Punjab

Fig.2.2 Sampling location in Mianwali-Punjab

2.2 *Laboratory Testing:*

Collected sand samples were brought in best available laboratories in the locality and were tested as per specifications. Different laboratories used were, Soil Mechanics and Foundation Engineering Lab, Civil Engineering Department UET Taxila, Material Testing Lab Askari Cement Factory Wah Cantt, Geotechnical Lab COMSATS University Wah Campus and Civil Engineering Lab, D.C.W Wah Cantt.

Specifications used for different tests include Grain size Distribution (ASTM-6913), Description and Identification (ASTM-D2488 − 09a), Specific Gravity (ASTM D 854-14), Minimum Dry Density, $\rho_{d\ min}$ (ASTM-D-4254-00) and Maximum Dry Density, $\rho_{d\ max.}$ (ASTM-D-4253-00), Minimum Void Ratio $e_{min.}$ (ASTM-4253-00) and Maximum Void Ratio $e_{max.}$ (ASTM-4254-00), Chemical Composition XRF Model: Cubix PW-2400, Angle of Internal Friction – (ASTM D3080) and Permeability Hydraulic Conductivity –ASTM D2434 (Constant Head).

3 RESULTS AND DISCUSSIONS

3.1 *Particle size Distribution using Sieve Analysis (ASTM-6913)*

Sand comprises of particles of various shapes and sizes. Sieve Analysis Test is used to separate particles into size ranges and to find quantitatively the mass of particles in each range. Sieve analysis test of sand sample collected from Khusab-Punjab consists of 99.01% of sand while 0.99% of fines particles while sand sample collected from Mianwali consists of

98.56% of sand and 1.44% of fines, whereas gravels were not present in samples collected from both of the sites. According to Unified Soil Classification System (USCS), samples collected from both sources comprise of poorly graded Sand (SP). Detail of D_{50} (mm), Cu, Cc are shown in Table 1, while Grain Size Distribution Curve is shown in Fig. 1.

Table-1 Particle Size Distribution Results

S/N0.	Sample I.D	Method	D_{50} (mm)	Cu	Cc	USCS
1	Ottawa-F-50	ASTM-6913	0.25	1.83	0.95	SP
2	D-KP	ASTM-6913	0.50	2.49	1.21	SP
3	F-MP	ASTM-6913	0.27	1.88	1.01	SP

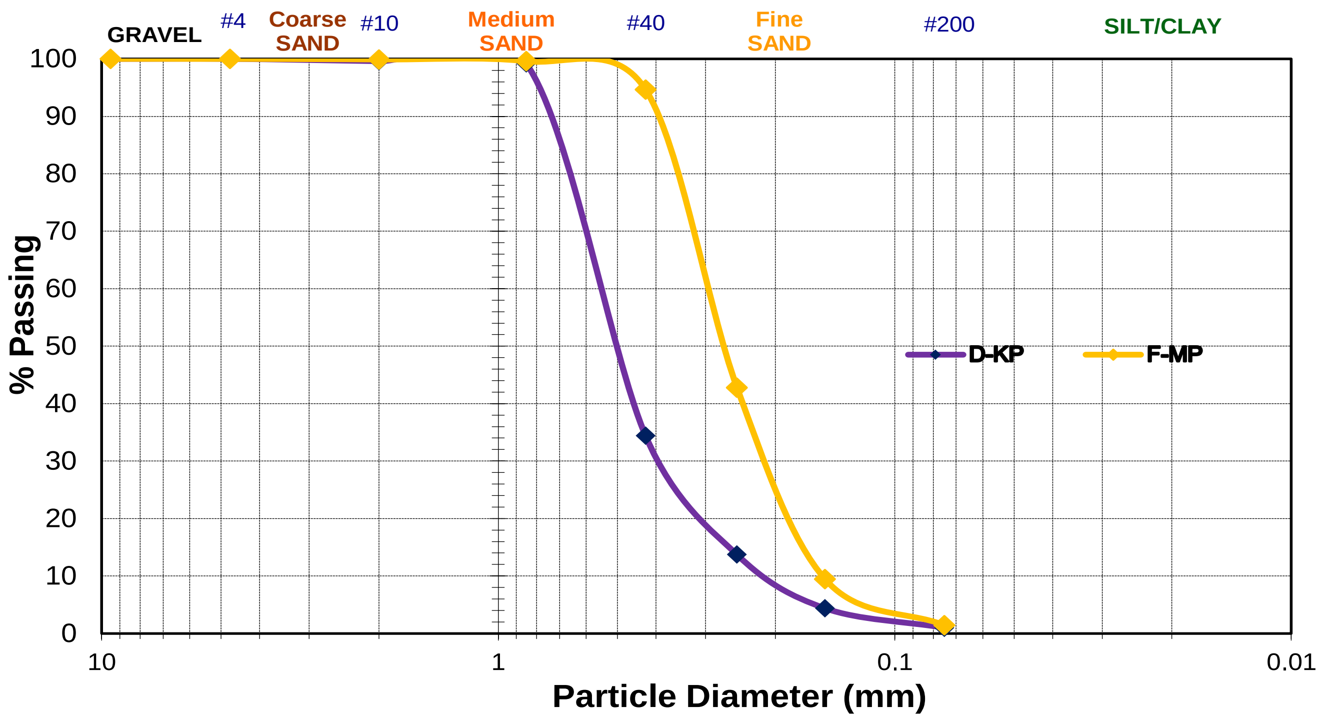


Fig.1 Grain Size Distribution Curve

3.2 *Description and Identification ASTM-D2488 − 09a*

Color is an important property of identifying soils of same geologic origin, as per specifications listed above color should be noted of wet samples of soils, wet samples collected from both sources showed grey color while dry samples collected from Khusab comprises of multi-color while sample collected from Mianwali mostly comprises of grey particles. Odor of samples is unusual/inorganic. while shape of sand particles is sub angular. Detail is shown in Table.2.

Table 2. Color, odor and shape of particles

S/N0.	Sample I.D	Color Wet Sample	Odor	Shape (Metallurgy Microscope)
1	Ottowa-F-50	-	-	Sub angular
2	D-KP	Grey	Unusual	Sub angular
3	F-MP	Grey	Unusual	Sub angular

3.3 Specific Gravity (ASTM D 854-14)

Specific Gravity of sand is closely linked with chemical composition/mineralogy of sand. Specific gravity values are shown in Table 3.

Table-3 Specific Gravity

S/N0.	LOCATION	Sample I.D	Method	G_S	% Difference
1	USA/CANADA	Ottawa-F-50	ASTM-D854	2.65	-
2	Khusab-Punjab	D-KP	ASTM-D854-14	2.65	0.00
3	Mianwali-Punjab	F-MP	ASTM-D854-14	2.66	1.00

3.4 Minimum Dry Density, $\rho_{d\ min}$ ASTM-D-4254-00 and Maximum Dry Density, $\rho_{d\ max.}$ ASTM-D-4253-00

In order to find Minimum Dry Density of sand mould having volume 2830 cm^3 was used while same mould and Vertically Vibratory table was used to determine Maximum Dry Density of sand.Tests results are shown in Table-4.

Table-4 Minimum Dry Density and Maximum Dry Density of Sand

S/N0.	Sample I.D	Location	$\rho_{d\ min}$ (kg/m^3)	$\rho_{d\ max.}$ (kg/m^3)	Difference % $\rho_{d\ min}$	Difference % $\rho_{d\ max.}$
1	Ottawa-F-50	USA/Canada	-	-	-	-
1.1	Ottawa-F-65	USA/Canada	1446	1759	-	-
2	D-KP	Khusab-Jhelum	1433.46	1718.14	0.87	2.38
3	F-MP	Mianwali-Indus	1311.95	1691.54	10.22	3.99

3.5 Minimum Void Ratio $e_{min.}$ ASTM-4253-00 and Maximum Void Ratio $e_{max.}$ ASTM-4254-00

Void ratio is important property for determining behavior of soil. It is defined as volume of voids present in sand divided by total volume of solids. Minimum Void Ratio and Maximum Void Ratio has been shown in Table-5. Void ratio values have been compared with Ottawa F-50 sand.

Table-5 Minimum and Maximum Void Ratio

S/N0.	Sample I.D	Location	e_{max}	e_{min}	Difference % e_{max}	Difference % e_{min}
1	Ottawa-F-50	USA/Canada	0.78	0.48	-	-
2	D-KP	Khusab-Jhelum	0.85	0.54	8.97	12.50
3	F-MP	Mianwali-Indus	1.03	0.57	32.05	18.75

3.5 Chemical Composition XRF Model:Cubix PW-2400 ASKARI CEMENT FACTORY WAH CANTT.

Chemical composition of sand was determined by using XRF techniques. It was found that sand sample collected from Khusab Pakistan has 72.05% of Silicon dioxide while Ottawa sand comprises of more than 99% of Silicon Dioxide. Detailed chemical composition values are showed in Table-6.

Table-6 Chemical Composition of Sand

S/N0.	Sample I.D	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %	K_2O %	Na_2O %	SO_3 %
1	Ottawa-F-50	99	-	-	-	-	-	-	-
2	D-KP	72.05	7.71	4.36	7.04	1.24	1.38	1.34	0.03
3	F-MP	68.58	12.76	4.93	5.04	2.19	1.80	2.23	0.03

3.6 Angle of Internal Friction –ASTM D3080

Angle of internal friction of sand is very important property as it is used to determine shear strength parameter of soils. Samples were re molded inside Laboratory as per in situ moisture content and bulk density and were tested under drained conditions. Angle of internal friction values are shown in Table-7.

Table-7 Angle of Internal Friction

S/N0.	LOCATION	Sample I.D	Method	Φ	Difference %
1	USA/CANADA	Ottawa-F-50	ASTM-3080	31.8	-
2	Khusab-Punjab	D-KP	ASTM-3080	33	3.64
3	Mianwali-Punjab	F-MP	ASTM-3080	32	0.63

3.7 Permeability Hydraulic Conductivity –ASTM D2434 (Constant Head)

Permeability of sand describes the ease with which fluid usually water can flow through pores, void spaces. Hydraulic conductivity of sands was found out by using Constant Head Permeability Test, *Permeability of loose sand was determined by using Minimum Dry Density while Permeability of dense sand* was determined by using Maximum Dry Density of sand. Detail of Permeability test is shown in Table-8.

Table-8 Permeability/Hydraulic Conductivity

S/N0.	Location	Sample I.D	$\rho_{d\,min}$ Loose Sand Kg/m^3	$\rho_{d\,max}$ Dense Sand Kg/m^3	Loose Sand K-cm/sec	Dense Sand K-cm/sec
1	USA/CANADA	Ottawa-F-50	-	-	0.038	0.025
2	Khusab-Punjab	D-KP	1433.46	1718.14	0.041	0.020
3	Mianwali-Punjab	F-MP	1311.95	1691.54	0.021	0.011

4 CONCLUSION

From above results and discussions sand samples have been characterized and it has been concluded that.

- All soil samples are poorly graded containing maximum 1.44% of fines.
- Based on physical and engineering properties, soil sample collected from Khusab Punjab having identification D-KP with grey color, sub angular shape of particles, specific gravity of 2.65, minimum dry density and maximum dry density of 1433.46 kg/cum and 1718.14 kg/cum respectively, minimum void ratio and maximum void ratio

values of 0.54 and 0.85 respectively, 72.5% of silicon dioxide as chemical composition, angle of internal friction 33^0 and with minimum and maximum premeability values of 0.020 K-cm/sec and 0.041 K-cm/sec is more closer

To Ottawa-F-50 and Ottawa F-65 Sand of USA, hence it is recommended to use Khushab sand as standard laboratory testing sand for research purposes in Pakistan. This source is recommended as standard source of sand for Geotechnical research/Laboratory Testing in Pakistan.

Practical implementation of recommended standard stand of Pakistan i-e Khusab Sand with little or nil modifications include usage in Laboratories for different research based activities (Geotechnical, Transportation, Concrete and Material Engineering), testing cement, concrete strength tests, Plastering walls (more closer to Stucco sand as per ASTM C897),Concrete preparation for construction activities, cement manufacturing etc.

REFERENCES

[1] Bastidas, A. M. P. Ottawa F-65 Sand Characterization. University of California, Davis. (2016).

[2] Naveed Ahsan, Iftikhar H. Baloch Strength Evaluation of Mortars of Lawrencepur, Chenab and Ravi sands and Concrete using Lockhart and Margalla Hill Limestone By Institute of Geology University Of Punjab. (1997).

[3] Ojuri, Oluwapelumi O., and David O. Fijabi. "Standard sand for geotechnical engineering and geoenvironmental research in Nigeria: Igbokoda sand." Adv. Environ. Res 1, no. 4 (2012): 305-321.

[4] Howard, A. K. (1984). The revised ASTM standard on the unified classification system. Geotechnical Testing Journal, 7(4), 216-222. (2012).

[5] Kramer, C. A. An experimental investigation on performance of a model geothermal pile in sand. (2013).

[6] Ojuri, O. O., and O. C. Agbolade. "Improvement of engineering properties of Igbokoda standard sand with shredded polyethylene wastes." Nigerian Journal of Technology 34, no. 3 (2015): 443-451.

[7] Dulcey-Leal, Eduardo, Fausto Molina-Gómez, and Lenin Alexander Bulla-Cruz. "Hydraulic conductivity in layered saturated soils assessed through a novel physical model." Dyna 85, no. 205 (2018): 119-124.

[8] El Ghoraiby, Mohamed, Hanna Park, and Majid T. Manzari. "Physical and mechanical properties of Ottawa F65 sand." In Model Tests and Numerical Simulations of Liquefaction and Lateral Spreading, pp. 45-67. Springer, Cham, 2020.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

SOLUTION TO FOUNDATION PROBLEMS IN COLLAPSIBLE SOILS OF KALLAR KAHAR, DISTRICT CHAKWAL, PUNJAB, PAKISTAN

[a] Engr. Rais Agha, [b] Dr. Naveed Ahmad
a: MS Student-Civil Engineering Department, UET Taxila-Pakistan, raisagha@gmail.com
b: Assistant Professor, Civil Engineering Department, UET Taxila-Pakistan, naveed.ahmad@uettaxila.edu.pk

Abstract **-**This study aims at providing the solution to Foundation Problems in Collapsible Soils of Kallar Kahar, District Chakwal, Punjab, Pakistan. Kallar Kahar is located in a semi-arid area. Most of the structures built in Kallar Kahar are cracked after or even during the construction stage. Generally, such cracks are related to bearing capacity problem i.e. either sub-soils possess low shearing strength or foundations undergo excessive settlement. Apparently, this is not the case. Soils are seen hard possessing moderate shearing strength and similarly chances of excessive settlement under existing structural loads seems to be unlikely. With no apparent reason, this is a challenge to Geo-technical Engineers of this region. One of such problematic sites is identified as the Fauji Foundation Hospital and Model School, Kallar Kahar. This study is carried out to identify the collapsible soils, assess the collapse potential and employ appropriate mitigation measures of this particular site and adjacent area. The research work is found to be of practical importance and beneficial for soil and foundation engineers to deal with collapsible soils. After the detailed analysis, it is concluded that soils present around the FFHS, Kallar Kahar, are potentially collapsible and needs proper attention in this regard.

Keywords- Collapsible Soils, Collapse Potential, Single Oedometer, Double Oedometer, Kallar Kahar

1 INTRODUCTION

Settlement of structures has always been a major concern for the Geo-technical Engineers. Generally, attention is given to the following causes of settlements:

- Most important is the structural loads on the footing.
- Presence of week soils.
- Weight of a recently placed fill.
- Lowering Ground water Table.
- Underground tunneling and mining.
- Lateral movements because of nearby excavations.

Another important cause of foundation settlement is Collapsible Soils. The purpose of this paper is to present an estimate of collapse potential and the anticipated settlements that are expected to be experienced by the foundations founded on collapsible soils in Kallar Kahar. Estimates were made using Single Oedometer (ASTM D5333) and also the Double Oedometer Test. In addition to this, research paper provides an opportunity to study comparison of two methods and to derive any relationship between the results of two types of oedometer tests. Engineering solutions to mitigate the potential for settlement are also recommended. The study of collapse potential of Kallar Kahar soils is never studied before and this research paper helps to improve the awareness of the risk posed by collapsible soils of Kallar Kahar.

2 RESEARCH METHODOLOGY

2.1 Problematic Site Identification

In our region, one of such areas where collapsible soils can be found is **Kallar Kahar**, District Chakwal. Fauji Foundation Hospital and Model School at Kallar Kahar is identified as a typical problematic site. This site is located on the off road of Motorway (M-2) and is opposite to Kallar Kahar Lake. Latitude and Longitude of site are noted as 32°46'57.74"N and 72°42'37.18"E.

Figure 1: Site Location

Mostly there are single story with one double and one triple story structures. Almost all of them have large and serious cracks. Officials informed us that they had got this site properly designed and constructed accordingly. When cracks were observed in relatively older buildings, they have reduced the bearing capacity to 0.50 kg/cm^2 which resulted in 3.65m x 3.65m footings, but still cracks are developed even during construction. Apparently, soils are dry and hard and reasons of settlement are beyond their imagination. They are facing this serious problem, which may result heavy monetary as well as human loss. Existing situation is well depicted in photographs followed by this page.

2.2 Field Sampling & Testing

High-quality undisturbed (block) samples were collected from nine (9) test pits and preserved and shifted to soil laboratory. Field Density Test by Sand Replacement Method (ASTM D1556) were also performed in all test pits along with the in-situ moisture content. Two water samples from nearby shallow water boreholes and one from the Kallar Kahar Lake were also collected. In addition to Test Pits and FDT, four boreholes were also drilled maximum up to 20 feet with the execution of Standard Penetration Tests (SPT). Results of SPT vary from 19 to Refusal. These results suggest that sub-strata present are very stiff to very hard.

2.3 Laboratory Testing

Following laboratory tests were performed on soil samples collected from field:

c. Index Properties

Index properties were measured on disturbed samples like grain size distribution (ASTM D422 & D4693), hydrometer analysis (ASTM D1140), Atterberg's limits (ASTM D4318), specific gravity (ASTM D854)) and also the soluble salts content. All of the samples are fine-grained soils and as per Uniform Soil Classification System (USCS) are classified as CL / CL-ML / ML. Results of index properties along with USCS classification and some important gravimetric-volumetric relationships like void ratio and initial saturation are shown in Table 1.

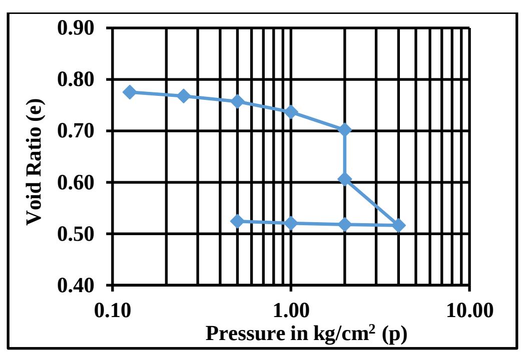


Figure 2: Results of Single Oedometer Test Pit-2

d. Collapse Potential

Soil Collapse Tests are performed by:

i) Single Oedometer Method

ii) Double Oedometer Method

2.4 *Single Oedometer Method*

Single Oedometer Method for the measurement of Collapse Index (I_c) is an ASTM standardized test with the designation D5333-03. This test measures one-dimensional collapse in the oedometer apparatus using standard test procedures such as described in the aforementioned standard. In Single Oedometer Test, in-situ moisture is maintained up to 2.00 kg/cm^2. At 2.00 kg/cm^2, sample is inundated and monitored for hydrocompression. Test result of TP-2 are plotted, as shown in Figure 2. Results of I_c of all nine tests by single oedometer vary from 1.825 to 5.465%.

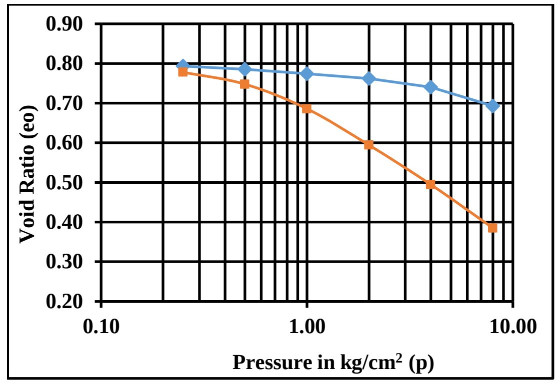


Figure 3: Results of Double Oedometer Test Pit-2

2.5 *Double Oedometer Method*

Double Oedometer Test Method for the measurement of the collapse potential was developed by Jennings and Knight (1956, 1957, 1975). Test result of TP-2 are plotted, as shown in Figure 3. Results of Collapse Index by double oedometer vary from 2.598 to 9.523%. Results of collapse index by Double Oedometer Method are generally found higher than those by Single Oedometer.

In addition to above, CBR Tests (ASTM D1883) were performed with lime as admixture in variable quantity to study its effect on MDD / OMC / CBR & Swell values of collapsible soils of the study area.

3 RESULTS AND DISCUSSIONS

3.1 *Index Properties*

Index properties were measured on disturbed bulk samples collected from 5'-0" of all Test Pits. Grains Size Analyses shows that fine content varies from 55 to 87%. Liquid limit (LL) values vary from 24.8 to 38.4 with plastic indices (PI) vary from 6.0 to 11.3. All of the samples are fine-grained soils and as per Uniform Soil Classification System (USCS) are classified as CL / CL-ML / ML. Results of Sieve Analysis, also the Atterberg Limits and USCS classification along with other index properties are shown in Table 1.

Table-1 Index Properties

Test Pit No.	Gravel	Sand	Fines	LL	PL	PI	USCS	w_N (%)	Dry Density γ_d (g/cm^3)	G_S	Void Ratio (e_o)	Saturation (%)
TP-1	02	30	68	30.3	22.7	7.6	CL	8.1	1.464	2.615	0.786	26.9
TP-2	-	16	84	27.2	21.2	6.0	CL-ML	7.0	1.427	2.600	0.822	22.1
TP-3	-	31	69	28.4	20.7	7.7	CL	7.1	1.516	2.647	0.746	25.2
TP-4	01	34	65	33.1	22.8	10.3	CL	11.0	1.441	2.604	0.709	40.4
TP-5	-	16	84	38.4	27.1	11.3	ML	18.1	1.488	2.727	0.833	59.3
TP-6	-	34	66	30.1	23.7	6.4	ML	18.0	1.459	2.727	0.869	56.5

TP-7	-	32	68	24.8	20.8	4.0	CL-ML	9.3	1.444	2.647	0.833	29.5
TP-8	02	43	55	31.3	22.3	9.0	CL	9.7	1.366	2.717	0.989	26.6
TP-9	-	13	87	28.9	22.0	6.9	CL-ML	5.7	1.452	2.633	0.813	18.5

Particle Size Distribution Curves of nine samples are shown in Figure 4.

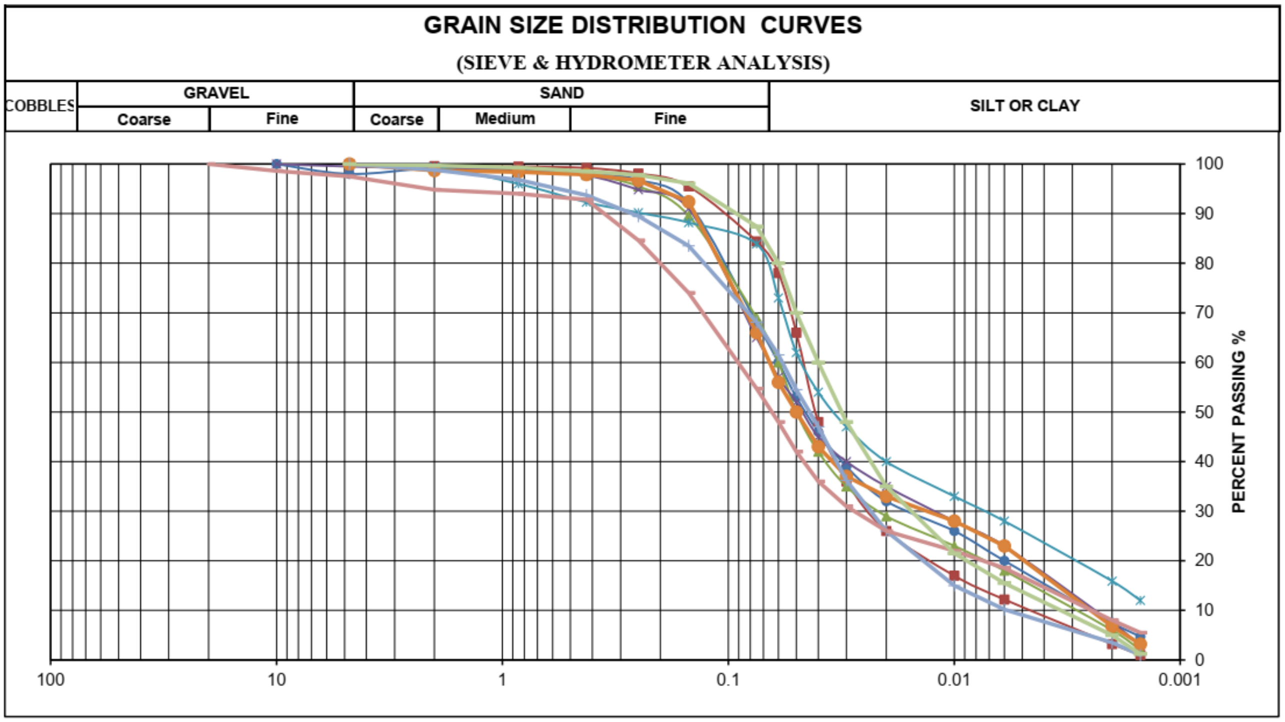


Figure 4: Particle Size Distribution Curves

3.2 *Laboratory Soil Collapse Tests*

a. *Results from Single & Double Oedometer Test*

Results of Collapse Index of all nine tests by single oedometer vary from 1.825 to 5.465% as shown in Fig. 5 and those by double oedometer vary from 2.598 to 9.523% as shown in Fig. 6.

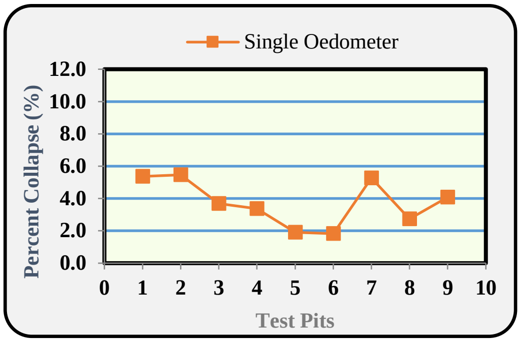


Figure 5: Results of Single Oedometer Test

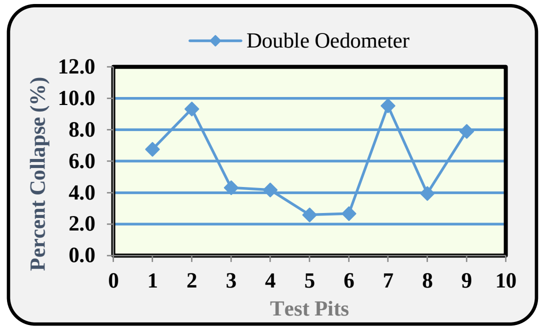


Figure 6: Results of Double Oedometer Test

b. Comparison of Collapse Index Obtained from Single Oedometer & Double Oedometer

Results from two methods are presented jointly in the Fig 10, which provides an opportunity to compare the results of two methods. Results of collapse index by Double Oedometer Method are generally found higher than those by Single Oedometer though mostly in a close range.

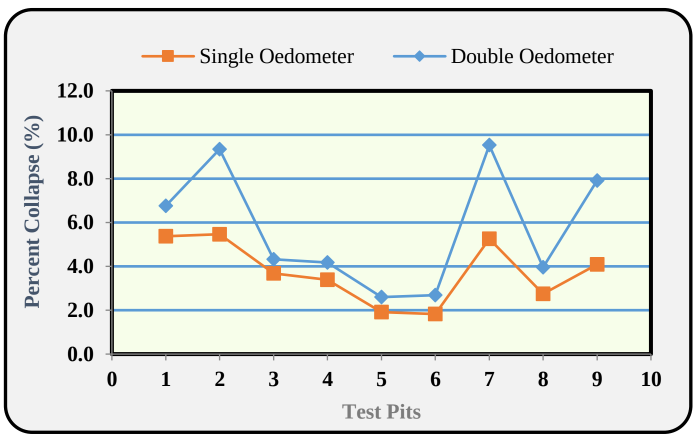


Figure 7: Comparison of Results of Single & Double Oedometer Test

Nine (9) collapse tests were performed on samples obtained from the selected site by two different methods, with the results shown in Figure 5, 6 & 7. The results are compared to the ranges categorized by ASTM 5333-03 as shown in Table 2, which corresponds to a degree of collapse mostly as moderate, with a few as slight. These results suggest that the subsoils present at Kallar Kahar have a high risk of collapse upon wetting.

Table 2 Collapse index categorized by ASTM D-5333 [3]

Degree of Collapse	**None**	**Slight**	**Moderate**	**Moderate to severe**	**Severe**
Collapse Index	0	0.0 – 2.0	2.1 – 6.0	6.1 – 10.0	>10.0

3.3 Comparison of Collapse Potential with Index Properties

Index properties of selected samples are given in Table 1 and Collapse Potential Test results are shown in Fig. 4. Comparison of different index properties with %C results provides a good opportunity to develop some relationship in between them. As can be seen from Fig 8 to 10 that with the increase in specific gravity, in-situ moisture content and liquid limit, percent collapse decreases. Fig 10 shows that with the increase in %change in saturation, percent collapse increases.

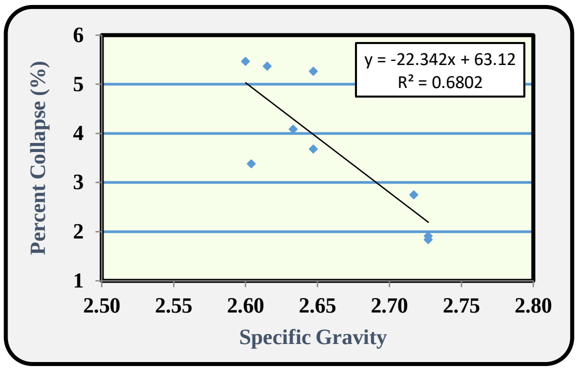


Figure 8: Comparison of % Collapse with Specific Gravity Test

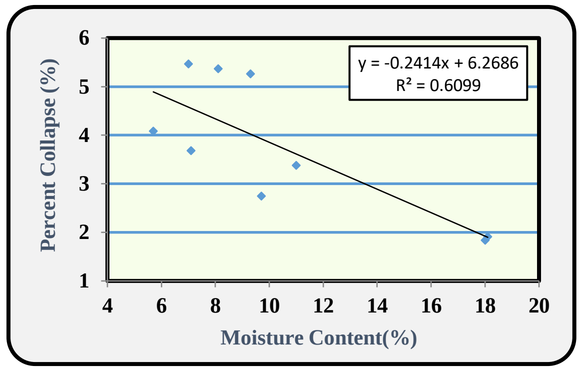


Figure 9: Comparison of % Collapse with Moisture Content Test

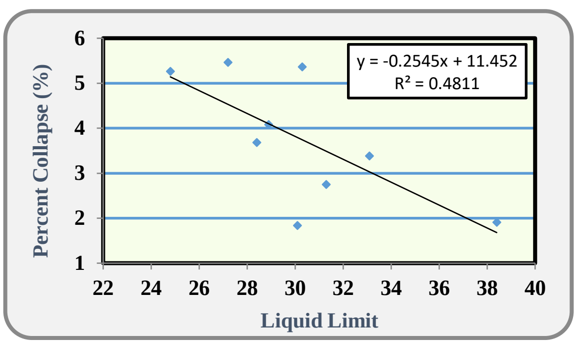


Figure 10: Comparison of % Collapse with Liquid Limit

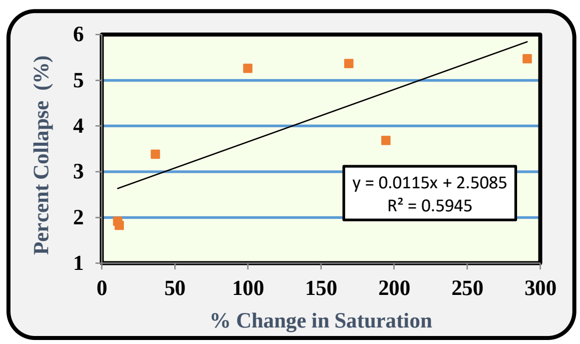


Figure 11: % Change in Saturation Vs Collapse

3.4 Effect of Lime on MDD, OMC, CBR & Swell of Collapsible Soils

a. Effect of Lime on MDD & OMC

Samples of TP-8 and TP-9 were selected to study the effect of use of lime on collapsible soil. Increase in lime content decreases the MDD values (Fig. 14) whereas OMC values increase with the increase in lime content.

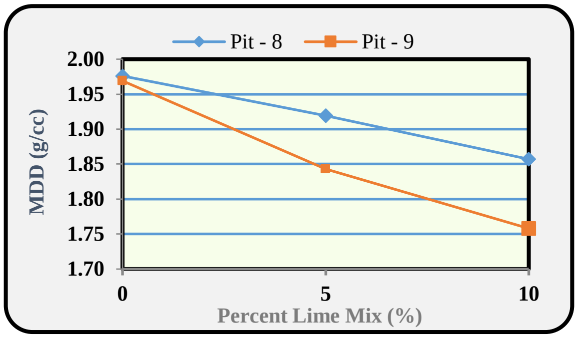


Figure 12: Variation in MDD with % Lime Mix

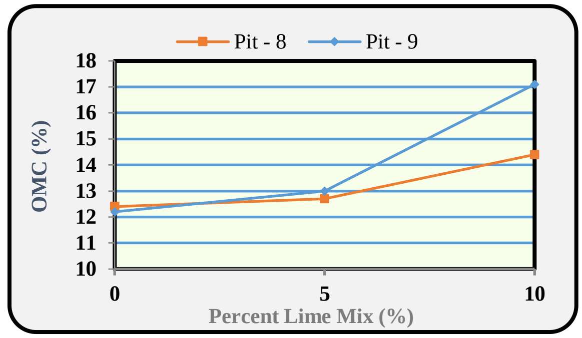


Figure 13: Variation in OMC with % Lime Mix

b. *Effect of Lime on CBR values*

In TP-8 (Fig 14), increase in lime content from 0 to 5% changes the CBR results intensely, but then increase from 5 to 10% increases CBR at slower rate. TP-9 shows same behaviour from 0 to 5%, but then a decrease is noted at 10% lime content (Fig 15) though still it is a good value.

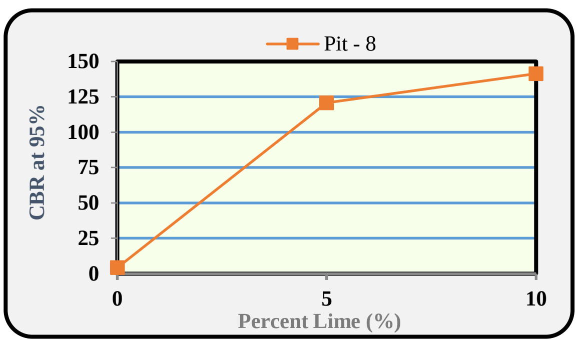


Figure 14: Variation in CBR with % Lime

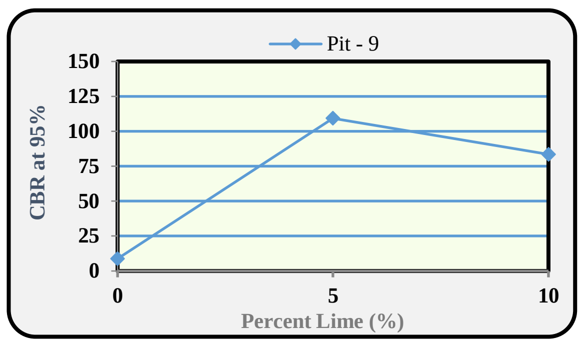


Figure 15: Variation in CBR with % Lime

c. *Effect of Lime on Swell values*

Interesting impact of variation in lime content is noted on swell values. CBR moulds at 10 blows, 30 blows and 65 blows show swell variably. But the most noticeable thing in both samples is the control in swell value though both samples show variable pattern.

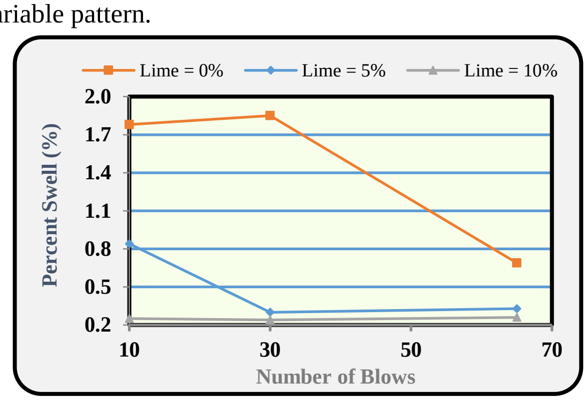


Figure 16: Variation in Swell with % Lime Mix in Pit – 8

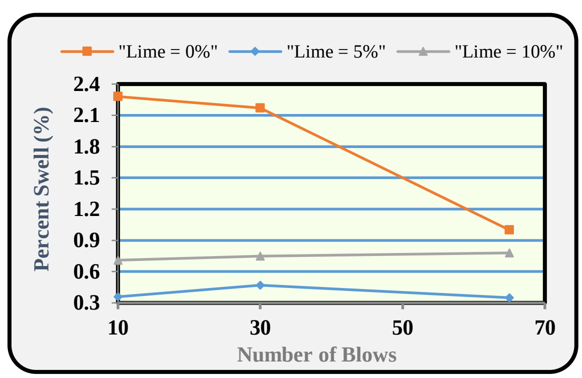


Figure 17: Variation in Swell with % Lime Mix in Pit – 9

3.5 Comparison of author's work with previous studies

It is the first study of this kind for this region and the results obtained in research are largely in confirmation with other authors like Mogadham et al (2006), Jennings and Knight (1975). However, results found in study partially confirm the findings of Handy, 1973. However, comparison on large scale needs detailed study and is beyond the scope of this research paper, but further study can be done in future."

4 SIGNIFICANCE & PRACTICAL IMPLEMENTATIONS

4.1 Significance

This study will serve to increase awareness about the settlement hazard posed by collapsible soils of Kallar Kahar. It will provide valuable information to the planners and developers and alert individuals to situations where additional site-specific investigation by an engineer or geologist would be appropriate.

4.2 Practical Implementations

The research work is found to be of practical importance and beneficial for soil and foundation engineers to deal with collapsible soils. Potential hazard is identified in Kallar Kahar soils. Data obtained from collapse potential tests not only help the geotechnical engineers to identify the severity of problem, which in turn help them to specify the remedial measures, but also help them to estimate the potential settlement due to hydrocollapse. This study will help foundation engineers in designing a safe foundation system for regions like Kallar Kahar.

5 CONCLUSION & RECOMMENDATION

5.1 Conclusions

1) After the detailed analysis of nine (9) samples from various locations of Fauji Foundation Hospital and School at Kallar Kahar, District Chakwal, it is concluded that soils present around the FFHS, Kallar Kahar, are potentially collapsible and needs proper attention in this regard.
2) Degree of collapse present at site is moderate to sever as per ASTM D5333 Test.
3) Apparently soils are quite hard with low moisture content, but due to collapse potential are certain to settle which is the reason of wall cracking in light load structures.

5.2 Recommendations

- Generally the artificial sources of infiltration are the major source of collapse. These sources include lined or unlined canals or sewerage drains, sub-surface pipelines and storage tanks, swimming pools, water reservoirs or septic tanks etc. Thus, it is recommended to take extreme care of all water-bearing surface or sub-surface structures or other features.
- If collapsible soils are present up to shallow depths as compare to foundation depth then same can be simply removed during excavation and foundations can be provided on underneath competitive or un-collapsible strata. For slightly deeper depths, this purpose can be achieved with the provision of basement.
- If collapsible soils are present up to deeper depths, which cannot be handled by removal, structural loads will have to be transferred to deeper strata by means of Pile Foundations. But still ground floor will require structural support.
- Another reason of collapse is low density. With the increase in density, collapsible soils can be used as an excellent load bearing stratum. For the purpose, all collapsible soils are required to be removed from influence zone depth and same must be placed again with proper compaction.
- Dynamic compaction i.e. dropping of several tons' heavy weights from several meters heights is another option, but cannot be recommended for a site where buildings or other structures exist in nearby.

5.3 Suggestions for Future Research

1) Further study of collapse potential is needed not only in Kallar Kahar but for other areas of Pakistan.
2) It is suggested to develop some strategy for field testing of such soils to collect some quantitative data by means of Plate Load Test on soaked and un-soaked soils.
3) Study to asses the loss in shearing strength should be performed based on extensive unconfined compression and direct shear tests on un-soaked and soaked samples.
4) Study to asses the relationship between collapse and salt content of Kallar Kahar soils should also be performed.

ACKNOWLEDGMENT

I really enjoyed this research work under the guidance of Geotech Faculty of UET Taxila, Pakistan, which enhanced my practical knowledge. I thank them all very honestly for their magnificent guidance and help. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCE

[1] Mahnam Roohi Hir, Michael Yousefadeh, and Rouzbeh Dabiri, 'Evaluation of Collapsibility Potential in Soil Layers Based on Practical Methods (Case study: Hir City-Ardabil Province)," *Advance Researches in Civil Engineering* Volume 1 No. 2, pp. 48-55, 2019

[2] Jennings, J. E. and Knight, K., "A Guide to construction or with materials exhibiting additional settlement due to collapse of grain structure", 6th Regional Conference for Africa on Soil Mechanics and Foundation Engineering, Durban, South Africa, September, 1, pp. 99-105, 1975

[3] *Tom* Schanz and *Hussein* H. Karim, "Geotechnical characteristics of some Iraqi gypseous soils", MATEC Web of Conferences 162, 2018.

[4] Rafie, B. M. A., Ziaie Moayed R., and Esmaeli. M., "Evaluation of Soil Collapsibility Potential: A Case Study of Semnan Railway Station", Electronic Journal of Geotechnical Engineering, EJGE; 13(G): pp. 1-7, 2008.

[5] Alan, J. L., & Robert, T. S. "Determination of collapse potential of soils", 1988.

[6] ASTM D5333-03. Standard Test Method for Measurement of Collapse Potential of Soils.

[7] Asuri, S., Konanur, P. R., & Sudhakar, M. R., "Collapse behavior of an artificially cemented clayey silt", 1995.

[8] Basma, A. A., & Tuncer, E. R. 1992, "Evaluation and control of collapsible soils", *Journal of Geotechnical Engineering*, *118*(10), pp. 1491-1504, 1992.

[9] Bell, F. G., & Bruyn, I. D., "Sensitive, expansive, dispersive and collapsive soils", *Bulletin of the International Association of Engineering Geology*, (56), pp. 19-38, 1997.

[10] Houston, S. L., & Houston, W. N., "Collapsible soils engineering", In *Unsaturated Soil Engineering Practice* (pp. 199-232). ASCE, 1997.

[11] Houston, S. L., Mahmoud, H. H., & Houston, W. N., "Down-hole collapse test system. *Journal of geotechnical engineering*, *121*(4), pp. 341-349, 1995.

[12] Ismael, N. F., Jeragh, A. M., Mollah, M. A., & Al-Khalidi, O., "Factors affecting the collapse potential of calcareous desert sands", In *Proceedings of the 9th Southeast Asian Geotechnical Conference* (Vol. 1, pp. 5-14)., 1987.

[13] Jennings, J. E., & Knight, K., "The additional settlement of foundations due to a collapse of structure of sandy subsoils on wetting", In *Proceedings* pp. 316-319, 1957

[14] Lovelace, A. D., Bennett, W. T., & Lueck, R. D., "*A test section for the stabilization of collapsible soils on Interstate 25* (No. MB-RR-83-1), 1982.

[15] Mashhour, I., "*Negative skin friction on single piles in collapsible soil* (Doctoral dissertation, Concordia University), 2009.

[16] Pells, P., Robertson, A., Jennings, J. E., & Knight, K., "*A guide to construction on or with materials exhibiting additional settlement due to" collapse" of grain structure* (No. Conf Paper), 1975.

[17] Pengelly, A. D., Boehm, D. W., Rector, E., & Welsh, J. P., "Engineering experience with in-situ modification of collapsible and expansive soils. In *Unsaturated Soil Engineering Practice* (pp. 277-298). ASCE, 1997.

[18] Rollins, K. M., & Rogers, G. W., "Mitigation measures for small structures on collapsible alluvial soils", *Journal of Geotechnical Engineering*,*120*(9), pp. 1533-1553, 1994.

[19] Souza, A., Cintra, J. C. A., Vilar, O. M., Alonso, E. E., & Delage, P., "Shallow foundations on collapsible soil improved by compaction", *Unsaturated Soils, Vols 1 and 2*, pp. 1017-1021, 1995

[20] Stumpf, A. J., "Collapsing Soil Hazards", In *Encyclopedia of Natural Hazards*, pp. 99-105, Springer Netherlands, 2013.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

APPLICATION OF PLAXIS FOR CALCULATING THE CONSTRUCTION STABILITY AND SOFT EMBANKMENT IN PROTECTING HA THANH RIVER, BINH DINH PROVINCE

[a] Thanh Nhan Duc Tran, [b] Zeeshan Ahmed, [c] Quang Binh Nguyen
a, c: Water Resources Department, University of Science and Technology - The University of Danang
duc.dut.wr@gmail.com
b: Water Resources and Glaciology Department, Global Change Impact Studies Centre (GCISC)
zeeshanahmed44@outlook.com

Abstract- The study aims to assess the anti-erosion efficiency of Ha Thanh embankment system to the downstream river sections nearby Dieu Tri bridge, which has been affected significantly by heavy floods, especially during flood season. With a great curvature, the loss of land (riverbank erosion) and the gain of land (riverbank accretion) are happening frequently and significantly. Besides, this study would clarify the model of stress, work ability and deformation calculation of embankment application in reality. With the significant development of natural and uncontaminated measures as Geotextile fabric Soft Rock and Vetiver grass in riverbank and coastal protection, this study would assess the stability through scenarios for both hard and soft embankments and comparison of these measures with current methods applied against erosion.

Keywords- Stability, flood, model of stress, deformation, embankment, geotextile fabric Soft Rock.

1 INTRODUCTION

The calculation of construction stability is often based on the theory using the method named "limit equilibrium" with the stable coefficient K [1]. Recently, due to the common use of computer software, Plaxis - a stable construction calculation is used commonly in dealing with geotechnical problems, due to its accuracy and ability to solve problems. For the slope stability problem, Plaxis is designed on a theoretical basis, which is a method of attenuating shear strength to determine the foundation stability coefficient. Besides, the use of soft embankments to replace the concrete embankments has shown many economic advantages [2].

The Ha Thanh river (Figure 1a) is one of the largest rivers of Binh Dinh Province. With a total amount of water around 675 million m^3, the Ha Thanh river supplies 7.3% of the total surface water out of 9,260 million m^3 annually. The distribution of flows resulted in large floods, the frequency of which is growing up rapidly and producing destructive floods in that area. Moreover, it causes serious erosion along the riverbank, and it also causes floods in the downstream areas. Due to low terrain and river branches unifying with the Kon river nearby Dieu Tri bridge, the flood drainage capacity has been affected greatly, especially during flood season. As a result, it causes heavy floods in the downstream, destroying inhabitant areas, important transportation systems as well as vital infrastructures of Quy Nhon city and Tuy Phuoc district, Vietnam [3].

This study has used 2 typical softwares, Geoslope and Plaxis for calculating the stability in two kinds of embankments i.e. soft and hard-concrete embankments in order to indicate and analyze the difference between two distinguished structural designs. Also, this study aims to evaluate the efficiency of these kind of designs and help engineers to choose the best method for their projects when comparing the stability analysis along with economic efficiency.

a.

b.

Figure 1: a) Map of Quy Nhon city, and b) Ha Thanh embankment system

The Ha Thanh embankment was built to decrease the erosion at southern areas of Ha Thanh river and the downstream area of Dieu Tri bridge. This embankment system is the only riverbank protection construction for the study area. Previously, due to lack of government actions and care, the area did not get attention from researchers. This paper has initiated steps to gain deeper insight of this study area. Many earlier studies used only one method to clarify purpose and results. In this research, authors combined Plaxis with Geoslope to enhance the quality of paper output.

2 MATERIAL AND METHODS

2.1 Software

Based on the topographical map, geological and working characteristics of coastal constructions affected by waves, the software - Plaxis V8.2 was used to evaluate the stability of the study area.

2.2 Methodology

The calculation phases were established based on initial stresses, the advantage is that the stresses are balanced in all cases, the calculation phases are shown as following:

2.3 Phase 1 (Plastic calculation)

This phase includes setup steps with necessary factors added for calculation in Phase 2. Flexibility calculations were based on deformation theory, small displacement assumptions could be applied appropriately. The calculation results of this step are the basis for the next calculation steps.

2.4 Phase 2 Stability calculation (Phi - C reduction)

This is an independent calculation step in PLAXIS that can be applied to many stages of construction or load bearing works. The calculation method is to gradually reduce the load capacity of the soil (internal friction angle and cohesion force) until the destruction of the soil mass occurs (surface slip - collapse). The ratio between the actual load capacity of the soil and the load at the time of failure is the safety factor that was needed.

2.5 Mohr - Coulomb (MC): Linear elastic-perfectly plastic

The Mohr-Coulomb model is a simple and well-known model which is used commonly nowadays. In Plaxis, Mohr-Coulomb could be considered as a first estimation of soil behaviour. The linear elastic part of the Mohr-Coulomb model is based on Hooke's law. The perfectly plastic part is based on failure criterion, formulated in a non-associated plasticity framework. The Mohr-Coulomb model consists of 5 basic parameters: elastic module E, Poison coefficient ν, cohesion force of soil C, internal friction angle φ and expansion angle of soil (dilatancy) ψ [4].

2.6 Input Data

Topographical data

The topographic data was collected mainly from geographical surveys.

Geological documents for soil and surface covering

Table 1 shows the basic mechanical properties of the ground layers. It is based on the actual geological report of the embankment in the south of Ha Thanh river.

Table 1-Mechanical properties of soil layers

Layers	Depth of Layers (m)	μ_{sat} (kN/m^3)	μ_{unsat} (kN/m^3)	μ $(radian)$	C (kN/m^2)	E (kN/m^2)
Surface	0 – 1.8	21.4	18.1	22.3	22.3	48.8×10^3
1	1.8 – 3.0	18.83	15.6	22	9.8	19.613×10^3
2	0.6 – 4.0	20	16.77	20	19.6	18.623×10^3
3	2.3 – 3.0	19.35	15.68	27.52	3.5	2.045×10^3

2.7 River water level

Based on the details in the stage of construction investment in the project, the design river water height was +6.82 m and dry river water height with 20 years frequency was about +2.5 m.

2.8 Vetiver grass

Vetiver grass (Figure 2a) is a special grass which is common in tropical and temperate regions of the world. This material plays an important role as a natural method for watershed protection. Indeed, it slows down the speed of river water and alleviate the siltation of drainage systems. Besides, it could decrease the bad effects of chemical productions, alleviate contamination, and makes soil clean. On the other hand, vetiver grass could endure significantly high level of metals especially with heavy metals. To control the soil erosion, vetiver grass has been applied as the most effective method for many areas [5].

a. b.

Figure 2: a) Vetiver grass against river erosion, and b) Geotextile Soft Rock R601 along the river

2.9 Geotextile Soft Rock R601

Soft Rock geotextile (Figure 2b) is one of the effective methods to decrease erosion along riverbank and coastal line. It is formed from local material and arranged suitably in front of protected areas. Geotextile Soft Rock R601 is used to control the erosion in waterfront construction, enhance the renourishment of beach, or to construct artificial reef. It can also be applied for many other purposes that requires high strength and the flexibility with long-term performance [6].

Material design

Geotextile width: 1.25 m, Geotextile length: 2 m, and Geotextile height: 0.4 m.

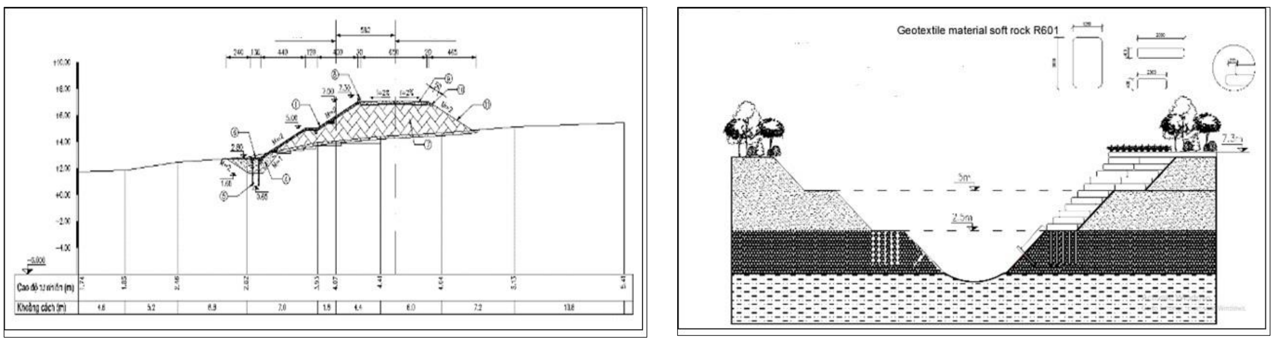
Material parameters

Tensile strength: 120 kN, weight of sand: 18.66 kN/m^3, weight of water: 10000 kN/m^3, surface slope - Taluy: 450, and deformation module E = 0.14 kN/m^2.

3 CALCULATION MODEL

[1] Calculation of model with hard concrete embankment

In this scenario, it was decided to calculate the hard-concrete embankment with height H = 7.3 m, width B = 6.5 m, roof coefficient m = 2, concrete with gradients MAC250 and backfill K = 0.98 (Figure 3a).



a. b.

Figure 3: a) Hard-concrete embankment section, and b) Soft-concrete embankment section

4 CALCULATION OF MODEL WITH SOFT CONCRETE EMBANKMENT

The calculation of the soft-concrete embankment with height H = 7.3 m, width B = 6.5 m, roof coefficient m = 1, concrete with gradients MAC250 and backfill K = 0.98 is shown in Figure 3b. The anti-erosion construction has been built with concrete (hard- concrete embankment), so the results of the calculation are stable with high ratio and it satisfy the required values according to the Vietnamese standard. The evaluation results are relatively good when compared with the allowable slip stability factor [K] (Table 2) [7]. Simulated results are compared with similar scenario from Geoslope in order to get the most objective assessments. When calculating stress and deformation of the embankment, the following scenarios were used:

4.1 Hard-concrete embankment

- Scenario 1: Height H = 7.3 m, width B = 6.5 m, roof coefficient m = 2, concrete with gradients MAC250, backfill K = 0.98 with the design river water height = +6.82 m.
- Scenario 2: Height H = 7.3 m, width B = 6.5 m, roof coefficient m = 2, concrete with gradients MAC250, backfill K = 0.98 with the dry river water height = +2.5 m.

4.2 Soft-concrete embankment

- Scenario 1: Surface maintained by Geotextile Soft Rock R601 combined with Vetiver grass. Its height H = 7.3 m, as section with design river water height h = +6.82 m.
- Scenario 2: Surface maintained by Geotextile Soft Rock R601 combined with Vetiver grass. Its height H = 7.3 m, as section with the dry river water height h = +2.5 m.

4.3 Scenarios simulation

The Ha Thanh embankment has serious erosion every year and it is necessary to propose scenarios (structural difference) to assess stability of the construction, then it could be recommended reasonable solutions such as typical aspects: the loading capacity and different structures based on the conditions of the construction site. Through the typical cross-section and based on the analysis of simulation models on Plaxis, the author proposes to use Mohr-Coulomb model and soft soil model to apply to 4 main soil layers. The calculation model based on the scenarios simulated on Plaxis 2D version 8.6 as follows:

Table 2-The anti-slip coefficient of concrete or rock embankment [K]

Loading capacity	**Construction level**					
	Rock foundation					
	Special	**I**	**II**	**III**	**IV**	**V**
Basic	1.20	1.15	1.10	1.10	1.05	1.05
Special	1.15	1.10	1.05	1.05	1.00	1.0
Loading capacity	**Other material foundations**					
	Special	**I**	**II**	**III**	**IV**	**V**
Basic	1.40	1.35	1.30	1.25	1.20	1.15
Special	1.25	1.20	1.15	1.10	1.05	1.05

4.4 Concrete revetment

The natural stones and concrete blocks could enhance the energy absorption of waves in coastal protection, due to minimizing reflection and wave run-up. Revetment is a passive solution which act against the wave effects , erosion caused by water surge, extreme weather conditions i.e. hurricane, flood, and currents. In this study, the mesh of the building with fineness also affects the simulation results. After finishing the steps of applying input data, the simulated water level for two phases of concrete revetment, h = +6.82m and h = +2.50m is as: Phase 1: Plastic analyst and Phase 2: Stability calculation (Phi - C reduction). The result of the stability coefficient - M_{sf} for the hard-concrete embankment shows that the coefficient k is 2.95 compared to the permitted stability coefficient (Table 3). The sliding surface brings hazards on upstream of embankment, with maximum dangerous sliding surface depth is + 6.75m (Figure 4). The result when simulated using Geoslope was similar to the sliding surface of concrete embankment, when using Plaxis on the upstream side.

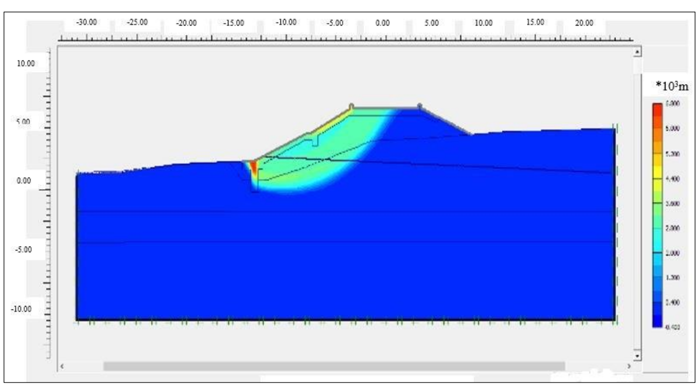


Figure 4: The location of dangerous sliding surface in (Concrete revetment), when having load (Plaxis)

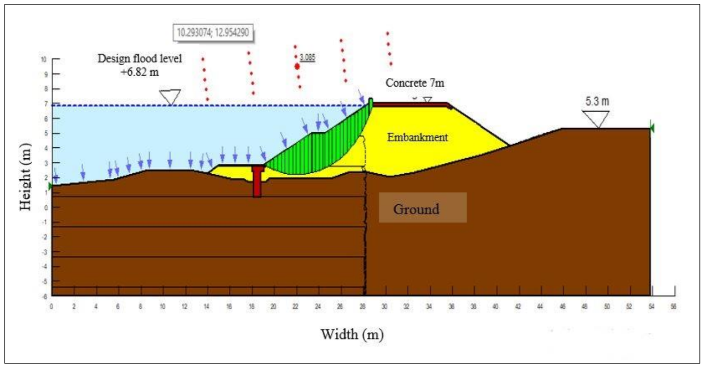


Figure 5: The location of dangerous sliding surface (Concrete revetment), when having load (Geoslope)

The most dangerous sliding surface depth was +3.2 m. These simulation in Plaxis and Geoslope showed the correlation. The location of dangerous sliding surface concentrated at the foot of the embankment satisfying the stability conditions. Therefore, the concrete revetment against erosion of the southern areas of the Ha Thanh river became a reliable solution for the construction of revetments.

4.5 Soft embankment

Soft embankment is a type of watertight construction (through revetment) to reduce the flow rate, cause sedimentation and prevent erosion. Soft embankment construction is a new solution to replace the current traditional method of concrete revetment with its superior advantages in construction and economy. To prove the effectiveness of this solution, it was decided to use soft embankments instead of concrete revetments in the actual simulation using Plaxis.

4.6 Scenario 1:

This scenario is quite similar to the simulation of concrete revetments, the input data was applied same as the simulation of soft embankment as follows: material parameters of Soft Rock R601, material design & parameters of Vetiver and data of water level. The water level applied for calculation in this scenario was designed water level with h= +6.82m. The dangerous sliding surface occurs on the upstream of the soft embankment, the maximum dangerous surface depth is in the riverbank. Sliding surface width is relatively large compared to concrete revetment scenario. The result shows that the coefficient k is 1.28 compared to the permitted stability coefficient according to Vietnamese standard TCVN 9902-2013 (Table 3) is good. The stability coefficient M_{sf} is 1.28 for the simulation with the design water level h = +6.82 m and the stability coefficient in the simulation in Geoslope is 2.31. When comparing two cases, it is realized that they have difference and this difference comes from the material used in separated scenarios. However, its parameters still satisfy the stability requirements. The authors continue to conduct the simulation for scenario 2 with the dry water level h = +2.5 m.

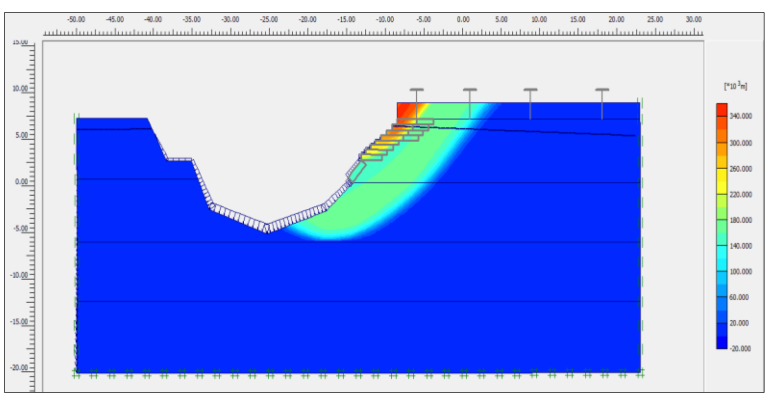


Figure 6: The location of dangerous sliding surface (soft embankment/scenario 1), when having load (Plaxis)

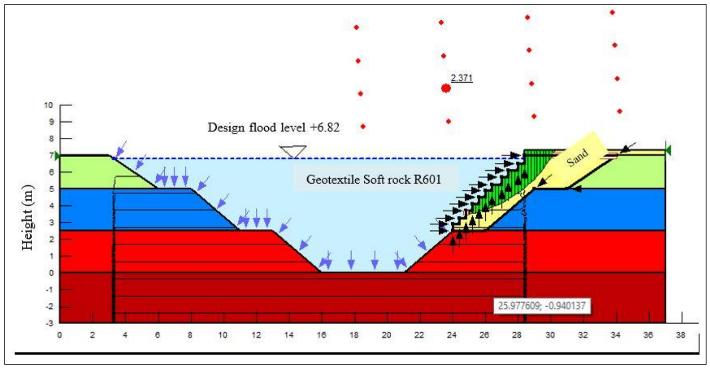


Figure 7: The location of dangerous sliding surface (soft embankment/scenario 1), when having load (Geoslope)

4.7 Scenario 2:

The authors used the Soft-concrete embankment section with the same input data and the dry water level h = +2.5m. The simulation results in Plaxis gives the stability coefficient, in case of the dry water level with h = + 2.5m, M_{sf} is 1.45 when compared with the simulated scenario in Geoslope with stability coefficient k = 1.43. There is a correlation in both cases using Plaxis and Geoslope respectively. Besides, Table 3 is a summary for all of scenarios conducted in this research. The authors found that the solutions of concrete embankment resulted in a higher stability coefficient K than that of soft embankments with the same categories. However, using Plaxis and Geoslope for stability calculations of soft embankment solutions also shows relatively good results and ensure stability when compared to Vietnamese standard TCVN 9902-2013 (Table 3). Therefore, soft embankment with Geotextile Soft Rock and Vetiver grass is also a feasible solution for construction nowadays. With regards to practical implementation in the industry, this study could be considered as a useful source for the Ha Thanh regulations. Its results could be used for construction projects in this area together with similar areas in central Vietnam.

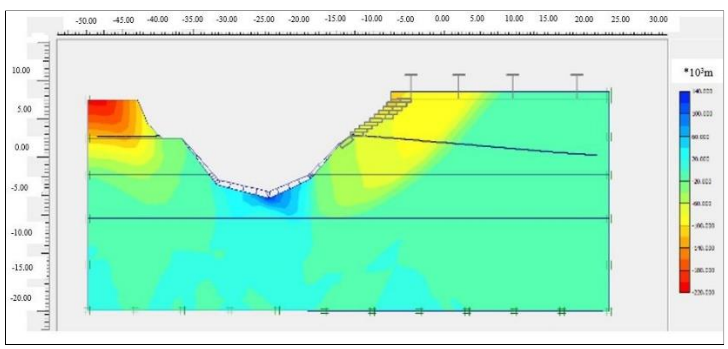


Figure 8: The location of dangerous sliding surface (soft embankment/scenario 2), when having load (Plaxis)

Table 3-The stability coefficient in different scenarios

Construction	Case	M_{SF} (Plaxis)	K (Geoslope)	[K]
Hard-concrete embankment	Scenario 1: +6.82m	3.2	3.10	1.20
	Scenario 2: +2.50m	2.95	2.82	1.20
Soft embankment	Scenario 1: +6.82m	1.28	2.37	1.20

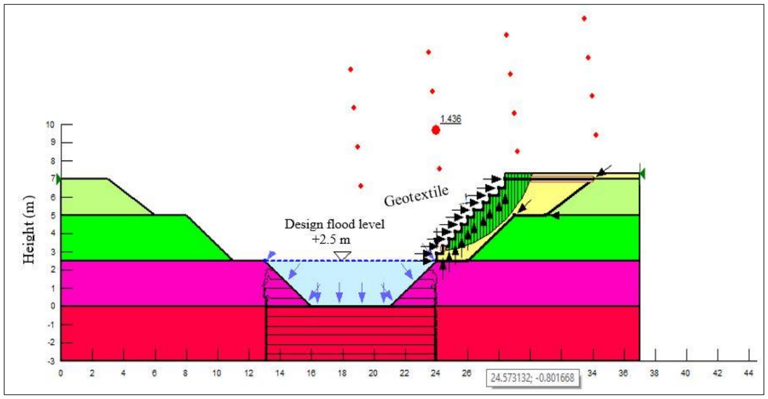


Figure 9: The location of dangerous sliding surface (soft embankment/scenario 2), when having load (Geoslope)

5 CONCLUSION

The study has simulated scenarios in order to assess the stability for the revetments of the southern bank of Ha Thanh and Binh Dinh rivers based on the physio-mechanical properties of the soil and designed water level using Plaxis. The stability parameters of calculations have been extracted for comparison with the stability coefficient [k] from calculations in Geoslope. Revetments with soft material such as Geotextile Soft Rock and Vetiver grass is feasible and brings good economic efficiency as well as practical efficiency. As a result, the expansion of soft embankment to similar embankments is feasible and brings optimal efficiency.

ACKNOWLEDGEMENTS

The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] H. Lin, W. Zhong, W. Xiong and W. Tang, "Slope stability analysis using limit equilibrium method in nonlinear criterion," *The Scientific World,* vol. 2014, pp. 1-7, 2014.

[2] F. Kasim, A. Marto, A. B. Othman, I. Bakar and F. M. Othman, "Simulation of safe height embankment on soft ground using plaxis," *Procedia APCBEE,* vol. 5, pp. 152-156, 2013.

[3] V. P. Tho, T. N. Luan, H. N. Xuan and T. N. Huyen, "Evaluating the impacts of flood to agriculture in Kon-Ha Thanh river basin area , Binh Dingh Province based on radar and GIS," in *International Symposium on Lowland Technology*, Hanoi, 2018.

[4] S. K. Ti, K. B. Huat, J. Noorzaei and S. M. Jaafar, "A review of basic soil constitutive models for geotechnical application," *Electronic Journal of Geotechnical Engineering,* vol. 14, pp. 1-18, 2009.

[5] D. Hengchaovanich, Vetiver grass for slope stabilization and erosion control with particular reference to engineering applications, Bangkok: Tech. Bull. No. 1998/2. Pacific Rim Vetiver N etwork. Office of the Royal Development Project Board, 1998.

[6] H. Wu, C. Yao, L. C. M. Miao, Y. L. Y. Zhong and T. Liu, "Review of application and innovation of geotextiles in geotechnical engineering," *Materials,* vol. 13, no. 7, 2020.

[7] T. 9902, "Hydraulic structures & requirements for river dike design," Thuy Loi University, Directorate for standards, Metrology and Quality – Ministry of Science and Technology of the Socialist republic of Viet Nam., 2013.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

THE USE OF PALSAR (D.E.M.) FOR MEGA FRACTURE ANALYSIS OF DABBAR ANTICLINE, SULAIMAN FOLD BELT, PAKISTAN

Mohsin Tariq [a,b,*], Muhammad Owais Zaib [b], Piero Di Carlo [a], Syed Tallataf Hussain Shah [b], Adnan [b], Muhammad Kashif [b], Altaf ur Rehman [b]
[a] DiSPuTeR, University of G D' Annunzio Chieti-Pescara, Italy.
[b] Department of Earth Sciences, COMSATS University Islamabad, K.P.K-Pakistan.
[*] Corresponding author: mohsin.tariq@unich.it

Abstract: The structural analysis has been carried out on the Dabbar Anticline using D.E.M. (Digital Elevation Model) data derived from Phased Array type L-band Synthetic Aperture Radar (PALSAR) of 12.5m resolution. The main structure is interpreted as upright, asymmetrical, gentle anticlinal fold based on the stereographic analysis. A total of three hundred fractures are marked across the Dabbar anticline having multiple lengths and orientations. One hundred and three fractures are marked on the Northern segment, sixty-one fractures are marked on the Central segment and one hundred and thirty-six fractures are marked on the Southern segment of the Dabbar anticline. Stereographic analysis and Rose diagrams show that the most major trend of lineaments is in NW-SE direction, parallel to maximum stress and termed as oblique fractures. This research in the Sulaiman Fold Belt indicates that mapping the structural features through D.E.M. data can provide a fair amount of geological information for understanding the characteristics of hydrocarbon reservoirs and engineering structures.

Keywords- PALSAR-D.E.M., Tensional fractures, Asymmetrical, Rose Diagrams.

1 INTRODUCTION

The breakage in a competent rock with no visible movement along its surface is known as a fracture. The Middle East is dominated by competent carbonate rocks, around 70% of the oil and 90% of the gas reserves are held within these fractured reservoirs [1]. Similarly, Pakistan also dominantly contain competent carbonates with hydrocarbon production history Figure 1 (C). Therefore, the knowledge of fractures is considered as very important in different kinds of geological studies (engineering structures, hydrocarbon reservoirs etc.) as they provide pathways for the fluid flow/transportation. In this context, types, trends, continuity, concentration and the origin of fractures are considered as important constraints [2]. To understand fractures, the present study is practiced on Dabbar anticline of the Sulaiman Fold Belt (SFB) by using D.E.M. data.

The Sulaiman Fold belt (SFB) is a lobate feature along the western margin of Indian plate mostly located in remote areas of Baluchistan, Pakistan Figure 1(A). This area is recognized as a prolific hydrocarbon province as well as seismically active, having exposed sedimentary strata from Permo-Triassic to Recent age of mostly platform origin. (Figure 1 (C), [3],[4],[5],[6]). The E-W trending Dabbar Anticline is a part of Western Sulaiman Fold Belt, lies between 30.02° to 30.11° N and 68.32° to 68.66°E. The surface geology of the anticline shows Dungan Formation of Paleocene age, which consists of competent limestone. It is bounded by strike-slip Khalifat Fault on its western side Figure 1(B). Due to its location in the remote area of Pakistan, the Digital Elevation Model (D.E.M.) data is used in this study to obtain the following objectives.

1. Fracture orientation.

2. Fracture classification.
3. Fold classification.
4. Stress and fractures relationship

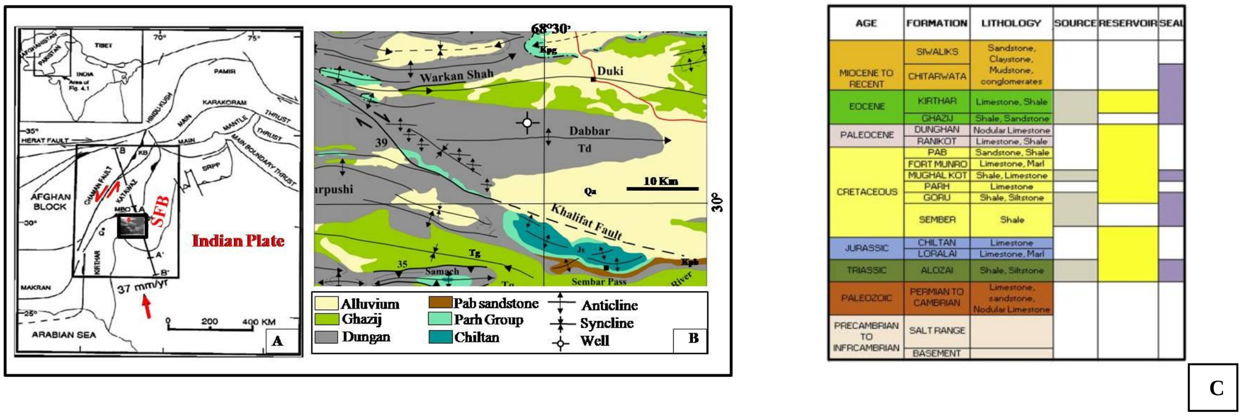


Figure 1: (A) Map showing the location [7], (B) Tectonic map [8], and,
(C) Stratigraphic column of the Sulaiman Fold Belt [6].

2 RESEARCH METHODOLOGY

The data and methodology are summarized in Figure 2 with details as follows:

2.1 Data set

The Digital Elevation Model data is a 3D representation of terrain surface used for structural analysis, physiographic mapping and neo-tectonic study. In this research, PALSAR data is used as a D.E.M. obtained from (https://www.asf.alaska.edu/).

2.2 Image processing

The image processing has been accomplished by using the following methods:

a. *Elevation Contouring*

3D data stored in PALSAR is utilized in ArcGIS to generate elevation contours of Dabbar anticline Figure 3.

2.3 Image enhancement techniques

The image is enhanced by changing a) sun azimuth angle, b) sun elevation (altitude) angle, and c) vertical exaggeration (z factor). Generally this technique is known as Hill Shade Tool (HT) and is available in ArcGIS. Different images are generated for the clarity of the structure for lineament marking.

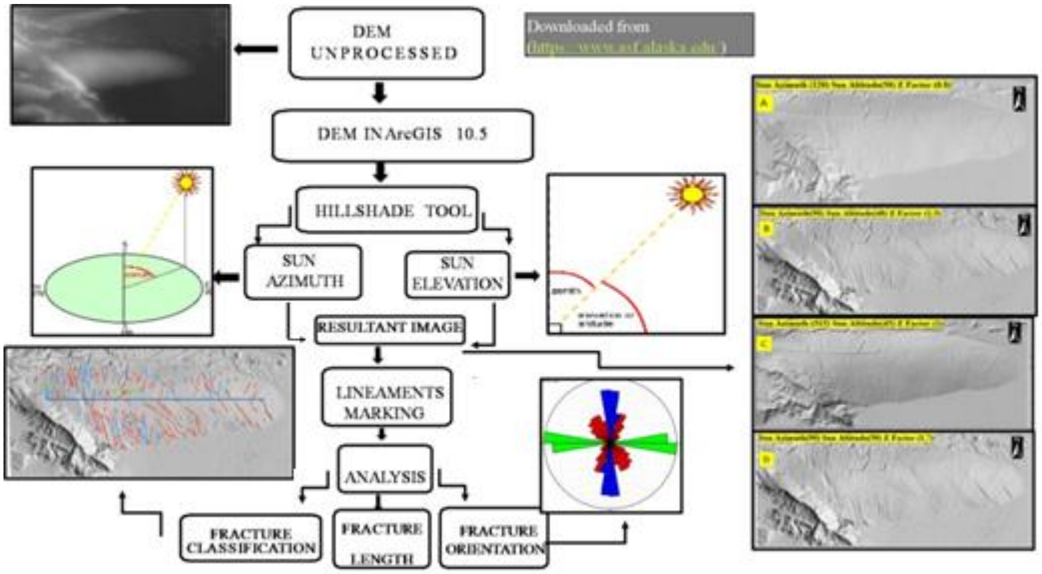


Figure 2: Workflow of the fracture analysis

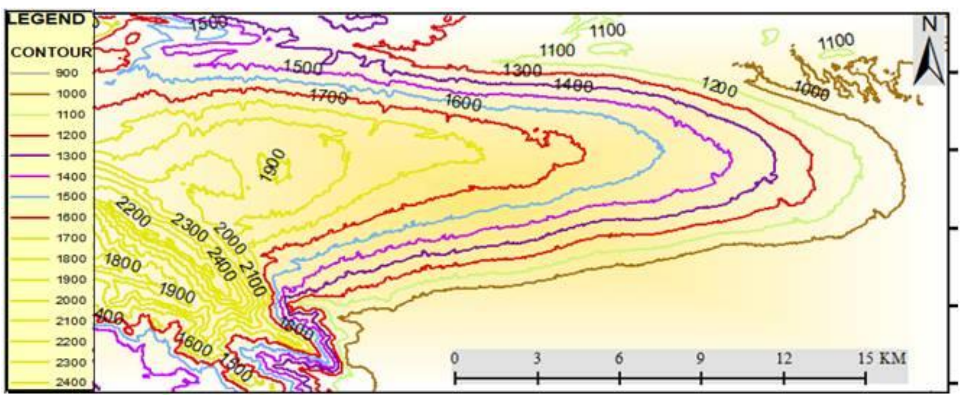


Figure 3: Elevation contour map of the Dabbar anticline

3 RESULTS

3.1 *Fold analysis*

The elevation contour map of Dabbar anticline is created by using a contouring tool in ArcGIS with a contour interval of 100meters (Figure 3). This helps in determining the strike and dip of northern and southern limb of Dabbar anticline using a three-point problem, which states that it is possible to calculate dip and strike of a horizon if the altitude of the horizon is known (Table 1,[2]).

3.2 *Fracture analysis*

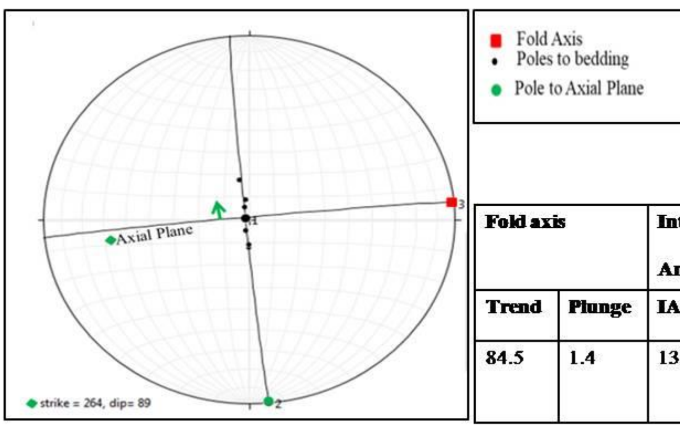
The processed images are interpreted in ArcGIS to mark the mega fractures. The total number of mega-fractures marked across the Dabbar anticline was 300. After marking the fractures of Dabbar anticline we have calculated the orientation and length of lineaments using GIS software. This data is analyzed with Stereonet software (10.2.9) in order to make rose diagrams.

Table 1: Calculated strike/dip of the Dabbar anticline						
	Western Part		**Central Part**		**Eastern Part**	
	Strike	Dip*	Strike	Dip	Strike	Dip
Northern Segment	91	12º NE	92	11º NE	108	5º NE
Southern Segment	78	18º SE	81	9º SE	73	6º SE

*Dip: Tan σ= change in elevation/ distance on map

4 DISCUSSION

Dabbar anticline is generally asymmetrical structure with a mean dip of about 10.1° of both limbs. The orientation of the fold axis is 84.5° with a plunge of 1.4°. Based on the inter-limb angle it is classified as gentle fold. Based on the axial plane, this fold is classified as upright fold. Generally, three types of fractures are observed to be developed across fold i.e. oblique, transverse (perpendicular to fold axis) and longitudinal (parallel to fold axis). In the case of the Dabbar anticline, the oblique fractures are dominantly observed with a general trend of NW-SE (Figure 5). The longitudinal fractures are rarely observed with the general trend of E-W direction.



Fold axis		**Interlimb Angle**	**Fold Type**
Trend	**Plunge**	**IA**	**FA**
84.5	**1.4**	**135**	**Gentle**

Figure 4: Stereographic analysis of anticline

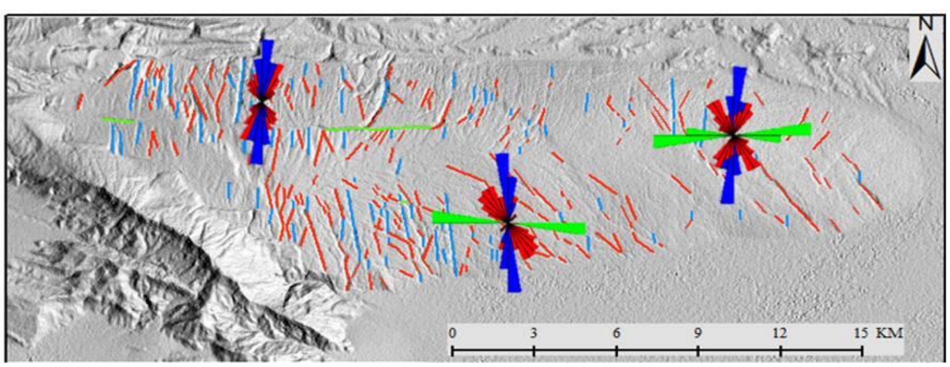


Figure 5: Fracture marking with their rose diagrams

5 CONCLUSIONS

This study is concluded with following points:

- The Sulaiman Fold Belt has hydrocarbon reserves with dominant carbonate reservoirs.
- Fractures play an important role in hydrocarbon production. Therefore, they were analyzed along an anticline. The analysis was carried out using PALSAR (D.E.M.) data and GIS software.
- The general trend of the anticline is E-W. Dabbar anticline is generally asymmetrical anticline with southern limb steeper (6°-18°) than the northern limb (5°-12°). The fold is classified as upright based on the axial plane and interlimb angle.
- A total number of 300 fractures were marked along this anticline and classified these fractures into oblique, transverse, and longitudinal sets based on relationship with anticline fold axis. The dominant fractures are oblique's sets with a general trend toward NW-SE.
- This research shows that the PALSAR (D.E.M.) data can be used for structural and fractures analysis in a remote and inaccessible area.

ACKNOWLEDGEMENTS

We acknowledge the support of Dr. Nangyal Ghani Khan, Assistant Professor and Dr. Faizan-ur-Rehman Qaiser, Lecturer, Department of Earth Science, CUI-Abbottabad Campus in this research work. We gratefully acknowledge the careful review and constructive suggestions by the anonymous reviewers.

REFERENCES

[1] M. Shepherd and G. American Association of Petroleum, *Oil field production geology*. Tulsa, Okla.: American Association of Petroleum Geologists, 2009.

[2] P. Maland, Billings. , *Structural Geology* 3ed. New Jersey 606: Prentice-Hall, 2006.

[3] A. Hilal, Raza., A. Riaz, M. Syed, Ali., and A. Jalil, "Petroleum prospects: Sulaiman Sub-Basin Pakistan," *Pakistan Journal of Hydrocarbon Research*, vol. 1, pp. 21-56, 1989.

[4] H. Ali, Kazmi. and A. Iftikhar, Abbasi., *Stratigraphy & Historical Geology of Pakistan*. Peshawar: Department & National Centre of Excellence in Geology, 2008.

[5] I. A. K. Jadoon, R. D. Lawrence, and R. J. Lillie, "Balanced and retrodeformed geological cross-section from the frontal Sulaiman Lobe, Pakistan: Duplex development in thick strata along the western margin of the Indian Plate," 1992.

[6] S. U. R. K. Jadoon, L. Ding, I. A. K. Jadoon, U. Baral, M. Qasim, and M. Idrees, "Interpretation of the Eastern Sulaiman fold-and-thrust belt, Pakistan: A passive roof duplex," *Journal of Structural Geology*, vol. 126, pp. 231-244, 2019.

[7] I. A. K. Jadoon and A. Khurshid, "Gravity and tectonic model across the Sulaiman fold belt and the Chaman fault zone in western Pakistan and eastern Afghanistan," *Tectonophysics*, vol. 254, pp. 89-109, 1996.

[8] I. Jadoon and M. O. Zaib, *TECTONIC MAP OF SULAIMAN FOLD BELT, PAKISTAN*, 2018.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad, Pakistan

Economic Comparison Of The Geothermal Heat Pump System And Conventional Water Heaters For Hot Water Supply In Apartment Buildings

[a*] Rehan Jamil, [b**] Abdulrahman K. S. Alhusayni
a, b: Department of Building Engineering, College of Architecture and Planning,
Imam Abdulrahman Bin Faisal University, Saudi Arabia
*rjamil@iau.edu.sa **abdulrahmankhalid97k@gmail.com

***Abstract*:** Saudi Arabia is in the process of dealing with energy availability, production, and consumption by foreseeing the possible issue of energy shortage in the country. Considering a huge demand for energy in the region the government has taken solid steps to address the issue and has formed various authorities to monitor, control, and manage energy consumption. The building industry is the highest consumer of energy where it is used for heating/air conditioning the indoor spaces, lighting, and running appliances and heating water during winters. This article presents an economic comparison of a conventional hot water heating system and another technique of Geothermal Heat Pump System (GHPS) which uses the heat energy of earth for heating water for domestic use. The effort has been made to assess the possible use of GHPS in apartment buildings in Saudi Arabia. Detailed design and analysis are conducted for both systems and a cost estimate is prepared. Life Cycle Costing is performed which includes the installation and operational costs of both the systems for a period of 5 years. The conventional system proves to be economical in terms of installation but in terms of energy consumption for the next 5 years, it becomes very expensive. Whereas the GHPS system shows almost one-third the total cost of the conventional hot water heating system showing a significant amount of energy consumption and financial benefit. The research shall prove to be beneficial for the construction and building industry in their efforts to reduce energy consumption by creating innovative designs and ideas.

Keywords: Hot water supply, geothermal energy, geothermal heat pump, economic comparison, Life Cycle Costing,

1 Introduction

Using sustainable means for the operation of a building during its lifetime has become as essential as the inhaling of oxygen to remain alive. Continuous use of fossil fuels has resulted in the depletion of the world's energy resources causing an escalation of fuel costs day by day. Buildings are the basic element in the world and have great importance in life where the person spends most of the time inside it. A building needs energy resources for the operation of mechanical, electrical, and plumbing services throughout its life. The energy consumption patterns show that buildings are the highest energy consumers with 41% of energy followed by transportation and industries with a consumption of around 30% of the share. For residential buildings, it has been found that around 73% of energy is used for heating and cooling of the inner spaces whereas almost 12% of the energy is consumed for heating the water for domestic use [1].

Due to having hot–arid climates, Saudi Arabia was named one of the 10 countries with the highest energy consumption per capita in 2014. According to a report published by the Saudi Energy Efficiency Centre (SEEC), the per capita energy consumption in the country is more than three times higher than the world average [2]. Moreover, according to an estimate, the electricity generation in the country consumes almost one-third of the daily oil production in KSA. Saudi Arabia introduced the SEEC and Saudi Green Building Council (SGBC) in 2010 to rationalize the production and consumption of energy to increase efficiency in the Kingdom [3, 15]. The center started collecting data from all sectors involved in the field of energy through surveys. In 2016, after the announcement of Saudi Vision 2030, this center started working more efficiently. Since then the major objective of the center is to find sustainable means of producing energy and to make the country independent of oil-based resources till the year 2030. Keeping in view the fast-paced reduction in the world's energy resources and the negative effect of burning fuel on the world's environment, various renewable energy resources are being discovered and explored at large. One of the renewable energy resources is geothermal energy.

The Earth's crust has an abundant storage of heat energy. This heat energy is environment friendly and has a lot fewer emissions as compared to burning fuel and fossils. Geothermal Heat Pump System (GHPS) is one of the methods by which this heat energy can be extracted and put to some use. A common GHPS comprises of following three components.

1. Heat pumps
2. Heat exchanger loop (horizontal or vertical)
3. Heat distribution unit

Heat pumps operate using electricity to drive compressors that provide the necessary work for the concentration and transport of thermal energy. Basic heat pumps operate on the vapor-compression refrigeration cycle. The working fluid within the heat pump is usually a refrigerant, with the selection dependent on the overall characteristics and requirements of the GHPS. The heat pumps move thermal energy between the heat exchanger loops buried below the earth and the heat distribution unit by controlling pressure and temperature through compression and expansion. In addition to few main components of the system such as, compressor, expansion, and reversing valves there are some minor components as well which include fans, piping, and controls that contribute to the whole operation [4]. The heat distribution system is then utilized to heat the water to the desired temperature of at least 45^{o}C.

There are two heat exchanger loop systems adopted for the extraction of geothermal energy; open-loop and closed-loop systems. The closed-loop system is used more commonly than the open-loop system for having more advantages. In the closed-loop system, the fluid is passed through the pipes buried under the ground and it has no direct contact with the earth. There are two major types of closed heat exchanger loop techniques; horizontal and vertical. The vertical loop consists of many vertical pairs of pipes connected at the bottom with a U-shaped connector. This assembly is bored into the ground at a depth of 50m to 150m depending upon the amount of heat being extracted with a spacing of 5-6m. One of the top ends of each pair of pipes is connected with the main supply pipe and the other is connected with the main return pipe of the GHPS as shown in Fig. 1a. This type of system is utilized when there is limited space as it requires a smaller area for installation. Also, it is considered for the areas where the impact of geothermal energy is found at larger depths. On the other hand, a horizontal loop system is laid at shallower depths but requires larger areas. The configuration of the pipes in the horizontal loop system is generally kept similar to the vertical loop system with an exception that the prior can either be laid in series or parallel configuration as shown in Fig. 1b and Fig. 1c respectively.

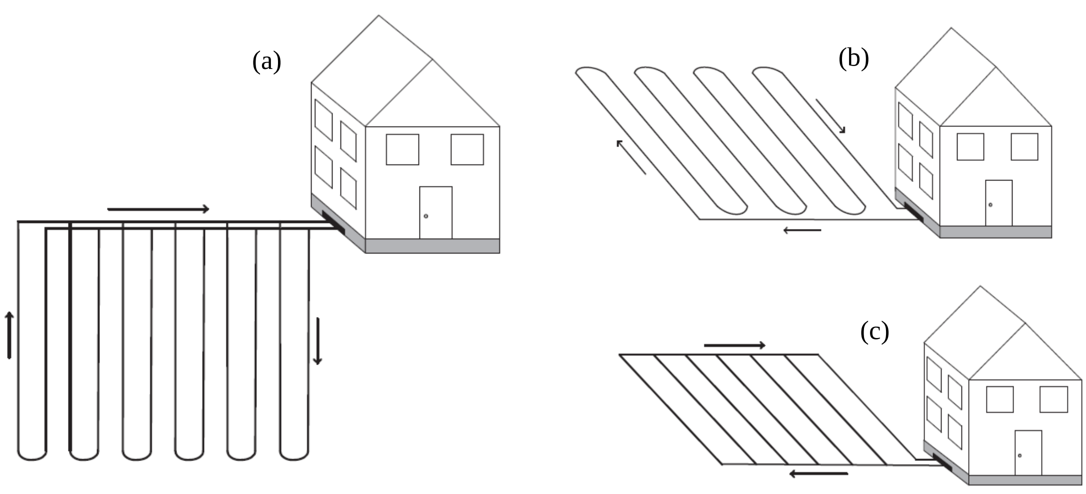


Figure 1: Heat exchanger loop system (a) Vertical, (b) Horizontal in series, (c) Horizontal in parallel [4]

The GHPS is being widely used in both residential and commercial buildings. Most common uses are found to be heating and air conditioning, however, few examples have been found for heating water as well. Kara and Yuksel [5] designed a geothermal heat pump in Turkey to supply hot water to flooring systems with a temperature of up to 45^{o}C. This method helped them in the conservation of electrical energy to heat water in boilers. Bloomquist [6] analyzed the GHPS for space heating by designing a hot water supply piping network for the whole community. In his research, he found the method quite efficient and concluded that the use of geothermal energy has a huge scope in future research works. Demirbas [7] has researched the prospects of geothermal energy and found that the reliance on geothermal energy shall increase gradually by the year 2040 around the globe. Mahmoudi et al. [8] used the geothermal energy to power the brackish water desalination unit in Algeria. He desalinated the brackish water to irrigate the farms and the greenhouse. He concluded that the system proves to be very efficient with 24h availability of power without producing any pollution and carbon emissions. In a few other articles, the utilization of geothermal energy has been explored for various purposes in Iceland and Turkey [9, 10]. A study has noticed that the installation and use of GHPS have been increasing at the rate of 10-30% in recent years [11].

To the best of authors' knowledge, no work has been performed and found in the literature for Saudi Arabia discussing the potential use of geothermal energy for heating domestic water. The purpose of this project is to analyze and discuss the possibility of utilizing geothermal energy for heating the water for domestic use. As the conservation of energy has been declared as one of the major tools in all of the green building certification authorities around the world including LEED, BREEAM, etc. [12], the article aims to conclude that the use of geothermal energy helps in saving energy in residential apartment buildings along with other financial benefits. The article shall help the stakeholders and provide them the guidelines for a sustainable building design.

2 EXPERIMENTAL PROCEDURES

2.1 Data Brief

The building selected for the case study is a multistorey residential apartment building located in Al Khobar, Saudi Arabia at 26^o 15' 13" N and 50^o 12' 29" E. The building comprises of 5 typical floors in addition to ground floor reserved for services and amenities. Each typical floor has a covered area of 375m^2 and has 8 apartments on each floor. A single apartment has three rooms, a living, a kitchen, and three toilets. Fig. 2 shows the 3D model of the apartment building created in eQUEST. It is an application that helps engineers and researchers to prepare the building model and professionally perform energy-related simulations and analysis.

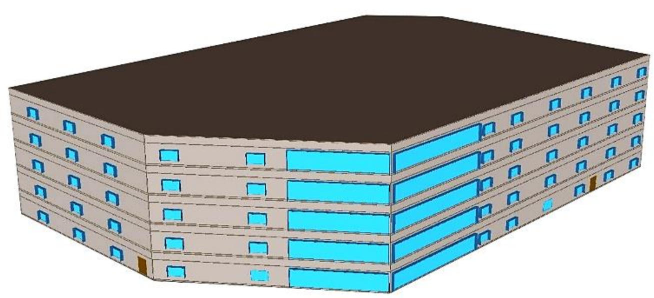


Figure 2: 3D Model of Apartment Building

The apartment building also has a vast area consisting of green lawns, playing area, and car parking within its site boundary. The water requirement of the building is being met by using freshwater obtained from the seawater desalination plant located on the eastern coast of Saudi Arabia in Al Khobar city.

2.2 Research methodology

The work methodology consisted of a stepwise procedure. Fig. 3 shows the workflow and details of each step. In the first step, the conventional hot water supply system was designed for the apartment building. In this system, it was considered that each toilet has a separate electric water heater and local hot water supply piping was provided within the toilet only. In the second step, the hot water system of the building was designed with the help of geothermal heat pumps. In this system, there was one pump taking supply from the main water storage reservoir at the ground floor and this pump let the water pass through various loops of pipes, having a thermally conducting material, buried under the ground. The water supplied by the first pump shall become hot by gaining the heat of the ground after passing through the loop network and shall be collected in a separate water tank. From this tank, the hot water was supplied to the whole building similar to a centralized heating system. The third step consisted of the hydraulic calculations for both systems.

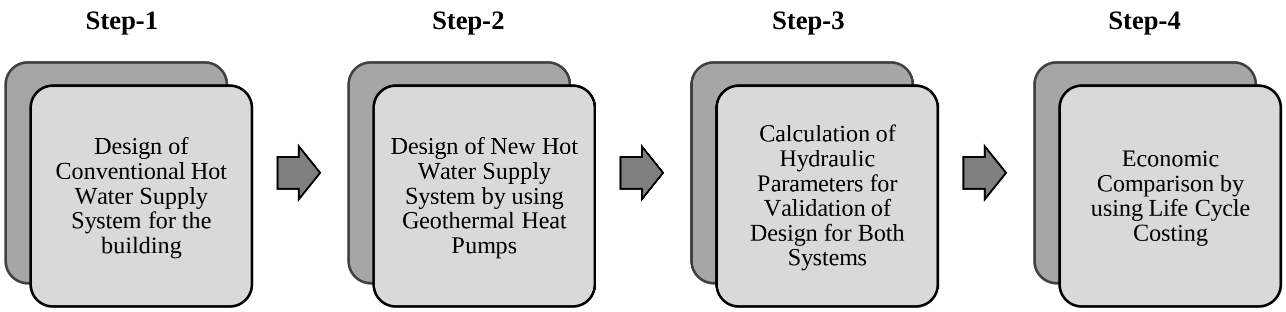


Figure 3: Methodology of Research Work

The EPANET 2.0 modeling tool was used for the analysis of hydraulic parameters of the designed layout. Slight modifications were done in the routing of pipes and their diameters to make the design correct and valid. The pipe frictional loss was calculated by using Hazen-Williams Eq. 1 as shown below [13, 16] whereas the pump power shall be calculated by using Eq. 2 which was used for GHPS.

$$h_L = \frac{10.67\ L\ Q^{1.85}}{C^{1.85}\ D^{4.87}} \qquad \text{.... Equation 1}$$

$$P = \frac{\Delta p\ Q\ \rho\ g}{1000\ \eta} \qquad \text{.... Equation 2}$$

Where h_L is the head loss in meters, L is the length of pipe under consideration (m), Q is the volume of flow of water in m^3/s, C is the Hazen-Williams roughness constant, D is the internal diameter of the pipe (m), P is the pump power obtained in kW, Δp is the total pressure required in meters, ρ is the density of water in kg/m^3, g is the acceleration due to gravity in m/s^2 and η is the pump efficiency. The final step consisted of the calculations of the cost of each system. The life cycle costing of both systems was done for a period of 5 years. The hydraulic and economic comparison along with results and discussion are presented in the next section.

3 RESULTS

3.1 Conventional Hot Water Supply System

The conventional hot water supply system for the apartment building was designed consisting of individual electric water heaters in each toilet. A general water heater having a capacity of 80 liters with an average power consumption of 1.2kW [14] was selected to be included in the design. A total of 125 water heaters were proposed to be installed in the building along with a CPVC (Chlorinated PolyVinyl Chloride) pipe system having diameters of 25mm and 20mm with respective thermal insulations.

3.2 Hot Water Supply by Geothermal Heat Pump System

In this step, an alternate proposal was prepared for the hot water supply system of the apartment building by using the technique of GHPS. The vertical heat exchanger loop system was adopted as there is less area available within the site boundary. 50mm diameter HDPE (High-Density PolyEthylene) pipes were proposed to be bored inside the earth up to a depth of 140m to extract heat from the earth. The heat exchanger loop system was designed as a recirculation system connected with the heat pumps. The heat distribution system was further connected to a network of CPVC pipes to supply hot water to the toilets of the apartment building as shown in Fig. 4a. After performing the hydraulic design of the whole system on EPANET 2.0, as shown in Fig. 4b, the total flow requirement of the apartment building was found to be 9.46lps ($0.00946 m^3/s$) with a required pressure of 70m. These hydraulic requirements suggested a pumping system having a power rating of at least 10kW by using Eq. 2. To calculate the pump power, the efficiency of the pump motor was assumed to be the most common value of 65% found in hydraulic pumps for domestic water supply. The pump characteristics curves generated by the program are shown in Fig. 5.

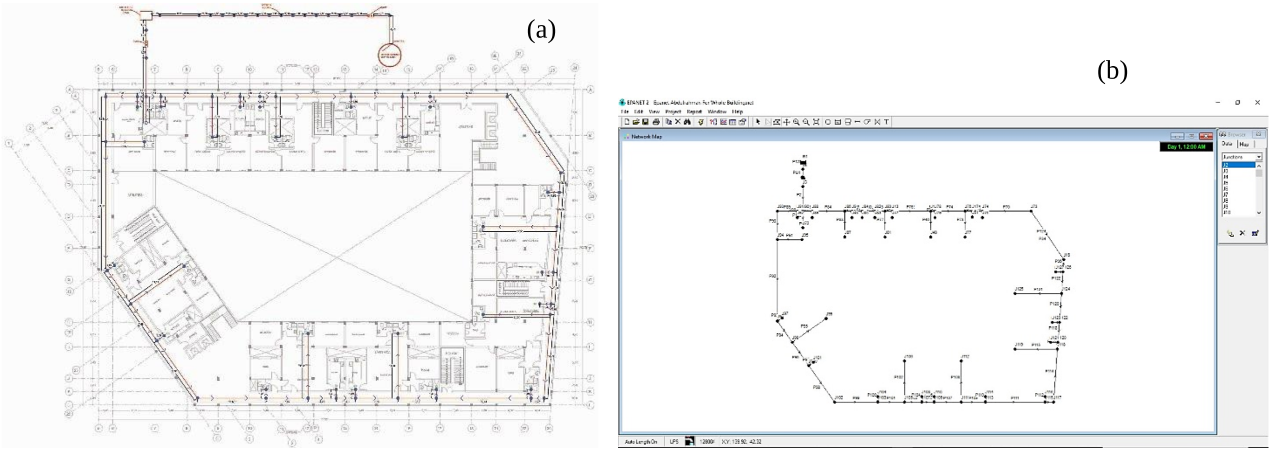


Figure 4: (a) Hot water supply layout of GHPS for a typical floor, (b) Hot water supply network model on EPANET 2.0

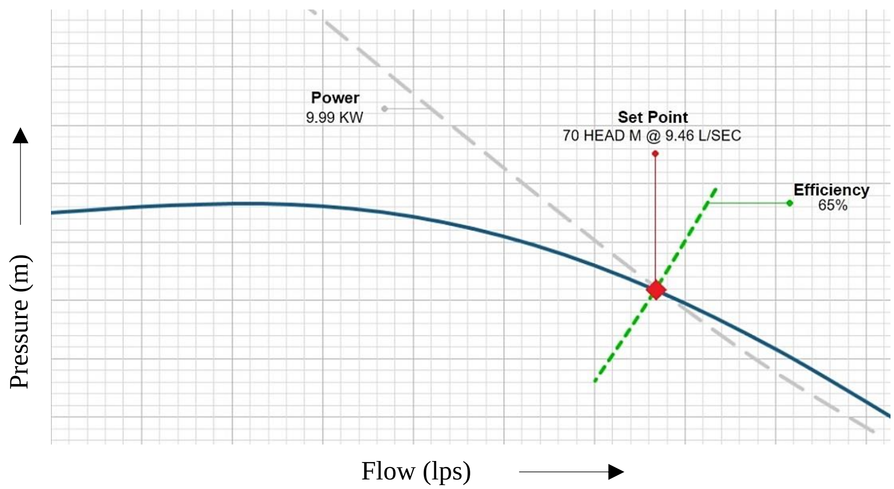


Figure 5: Characteristic curves of designed geothermal heat pump

3.3 Economic Comparison of Both Systems by Life Cycle Costing

After validation of the hydraulic design of both proposed systems, a detailed comparison was prepared for the economics involved in the execution of the design. Life Cycle Costing was performed which included the installation and operational costs of the systems for a period of 5 years. The cost of all materials involved in the design was obtained from the local markets of the Eastern Region of Saudi Arabia. A brief comparison is given in Table 1.

The other part of the LCC is the operational cost related to both systems. For a hot water system working in the Eastern Region of Saudi Arabia, it is assumed that the duration of working of such systems is almost 4 months because the winter season prevails from the mid of November till the mid of March, as shown in Fig. 7. For the case of a conventional hot water supply system, the water heaters are generally kept on for the whole season which makes around 2,880 hrs. of continuous working. Considering the required number of water heaters, the apartment building understudy would consume a huge amount of 432 MWh of energy each season.

Table 1: Bill of Quantities and Cost Estimate for Installation of Proposed Systems

Items / Materials	Rate (SAR)	Conventional Hot Water System	Geothermal Heat Pump System

		Quantity	**Cost (SAR)**	**Quantity**	**Cost (SAR)**
Electric water heater (Cap. 80 lit.)	550 Each	125 No.	68,750	-	-
Supply and installation of GHPS unit including pumps, compressor, electric control panels, valves, etc.	50,000 Each	-	-	1	50,000
Supply and installation of 50 mm dia. HDPE pipes as heat exchanger loops including boring and laying of pipes inside the earth	55/m	-	-	1,600 m	88,000
Supply and installation of 50 mm dia. CPVC pipes for hot water supply with thermal insulation	40/m	-	-	50 m	2,000
Supply and installation of 40 mm dia. CPVC pipes for hot water supply with thermal insulation	31/m	-	-	350 m	10,850
Supply and installation of 32 mm dia. CPVC pipes for hot water supply with thermal insulation	26/m	-	-	630 m	16,380
Supply and installation of 25 mm dia. CPVC pipes for hot water supply with thermal insulation	21/m	375 m	7,875	430 m	9,030
Supply and installation of 20 mm dia. CPVC pipes for hot water supply with thermal insulation	18/m	1,000 m	18,000	1,070 m	19,260
Supply and installation of 15 mm dia. CPVC pipes for hot water supply with thermal insulation	15/m	750 m	11,250	650 m	9,750
Total			**105,875**		**205,270**

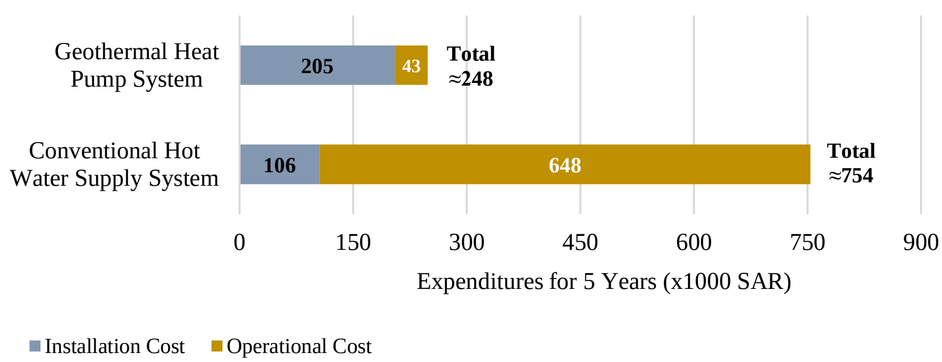


Figure 6: Economic Comparison of Conventional Hot Water Supply and GHP System for 5 years

On the other hand, the energy consumption of a GHPS is quite low, as it includes a hot water return loop system which reduces the load on the system by bringing back the unused water with sufficient retained heat instead of heating it again and again. Moreover, there is only one recirculating pump working for the system in addition to the compressor and heat distribution unit. The energy consumption for GHPS thus comes out to be 28.8 MWh for the whole season when the system is considered to be working for the same number of hours. The consumption tariffs as defined by the Government of Saudi Arabia are SAR 0.3/kWh. Hence for a period of 5 years, the cost of energy consumption for a conventional hot water supply system can be estimated to around SAR 648,000. Whereas this value for a GHPS comes out to be only SAR 43,200. Although the installation cost of GHPS is higher than the conventional hot water supply system, however, it proves to be very economical in a long run because of very low energy consumption, as proved by the LCC calculations. The comparison of installation and operational costs are shown in Fig. 6.

4 Practicality Of The Research

The temperature of the internal surface of the Earth at a specific location remains almost equal to the annual average temperature of the surroundings above that surface, as proved by the phenomena of thermal inertia. It is also proved by the fact that during winter the internal surface of Earth feels warm and it feels cold during the summer season. As shown in Fig. 7, the annual average temperature of Dammam, a major city of the Eastern region of Saudi Arabia, is found to be 27.2 ºC [17]. It can be observed that the temperature of Earth's crust, which is the average annual temperature, remains higher from the mid of November till the mid of March. Hence during this duration of 4 months, there is a huge potential of extracting energy from the surface of the Earth in the Eastern region of Saudi Arabia by using GHPS for hot water supply.

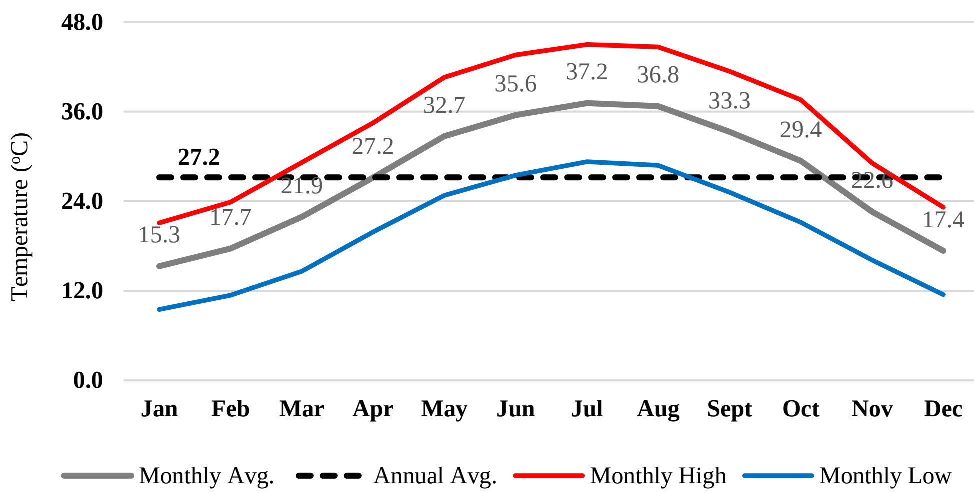


Figure 7: Temperature chart for Dammam based on the data collected from 1980 to 2016 [17]

As discussed in Section-1, most of the work related to GHPS, found in literature is done for space heating, floor heating, and water filtration techniques. However, the results obtained in this research are complimenting the results of the previous studies wherever water is involved as the heat absorbent. The methodology discussed in this research can widely be applied for apartments, hotels, and such building types where the consumption of hot water is comparatively higher.

5 Conclusion

An economic comparison was conducted for a conventional hot water heating system by using individual electric water heaters in each toilet against the technique of supplying hot water by using a geothermal heat pump system for an apartment building in Saudi Arabia. After the hydraulic design and analysis of both systems, a detailed cost estimate was prepared by obtaining the price of each material from the local markets in the Eastern region of Saudi Arabia. The installation cost for a GHPS was found to be almost doubled the cost of the installation of electric water heaters. However, the energy-related calculations for five winter seasons showed that the cost of energy consumption of electric water heaters was too high as compared to the energy consumed by a GHPS for the same period. The LCC technique was used to see the overall impact of the cost of both systems for a period of 5 years and it was found that the conventional hot water heating system cost around SAR 754,000 whereas, the same for GHPS was found to be three times less, valuing up to SAR 248,000. The GHPS system has shown a significant drop in energy consumption for an apartment building. Though the system is not much common yet however it must be adopted by the construction experts and designers to play their role in the Country's efforts of reducing the reliance on oil-based resources and achieving the goals of Saudi Vision 2030.

ACKNOWLEDGEMENT

The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] Anisimova N., "The capability to reduce primary energy demand in EU housing", Energy and Buildings, Vol 43, No. 10, pp. 2747–2751, 2011

[2] Annual Report 2018, Saudi Energy Efficiency Center (SEEC), <https://www.seec.gov.sa/sites/default/files/blog_files/annual-report-2018.pdf>, 2018

[3] Felimban A., Prieto A., Knaack U., Klein T., Qaffas Y., "Assessment of Current Energy Consumption in Residential Buildings in Jeddah, Saudi Arabia", Buildings, Vol. 9, pp. 1-19, 2019

[4] Self S. J., Reddy B. V., Rosen M. A., "Geothermal heat pump systems: Status review and comparison with other heating options", Applied Energy, Vol. 101, pp. 341-348, 2013

[5] Kara Y. A., Yuksel B., "Evaluation of low temperature geothermal energy through the use of heat pump", Energy Conservation and Management", Vol. 42, pp. 773-781, 2001

[6] Bloomquist R. G., "Geothermal space heating", Geothermics, Vol. 32, pp. 513-526, 2003

[7] Demirbas A. H., "Global Geothermal Energy Scenario by 2040", Energy Sources, Part A, Vol. 30, pp. 1890-1895, 2008

[8] Mahmoudi H., Spahis N., Goosen M. F., Ghaffour N., Drouiche N., Ouagued A., "Application of geothermal energy for heating and freshwater production in a brackish water greenhouse desalination unit: A case study from Algeria", Renewable and Sustainable Energy Reviews, Vol. 14, pp. 512-517, 2010

[9] Kaygusuz K., Kaygusuz A., "Geothermal energy in Turkey: The sustainable future", Renewable and Sustainable Energy Reviews, Vol. 8, pp. 545-563, 2004

[10] Ragnarsson A., "Utilization of geothermal energy in Iceland", 14th 'Building Services, Mechanical, and Building Industry Days' International Conference, Debrecen, Hungary, 2008

[11] Sarbu I., Sebarchievici C., "Using Ground-Source Heat Pump Systems for Heating/Cooling of Buildings", Advances in Geothermal Energy, Chapter 1, Intech Open, pp. 1-36, 2016

[12] Shaawat M. E., Jamil R., "A guide to environmental building rating system for construction of new buildings in Saudi Arabia", Emirates Journal for Engineering Research, Vol. 19, No. 2, pp. 47-56, 2014

[13] Jamil R., " Frictional head loss relation between Hazen-Williams and Darcy-Weisbach equations for various water supply pipe materials", International Journal of Water, Vol. 13, No. 4, pp. 333-347, 2019

[14] Saudi Ceramic Electric Water Heaters Catalogue 2017, <https://www.saudiceramics.com/pdf-catalogue/SCCWaterHeater Catalogue2017.pdf>, 2017

[15] Shaawat M. E., Jamil R., Al-Enezi M. M., "Analysis of challenges in sustainable construction industry by using analytic hierarchy process: a case study of Jubail Industrial City, Saudi Arabia", Vol. 1, No. 2, pp. 109-122, 2018

[16] Rossman L. A., "EPANet 2 Users Manual", National Risk Management Research Laboratory, United States Environmental Protection Agency, Cincinnati, OH, USA, 2000

[17] Average Weather in Dammam, Weather Spark, <https://weatherspark.com/y/104953/Average-Weather-in-Dammam-Saudi-Arabia-Year-Round>, 2020

INDUSTRIAL WASTE WATER ANALYSIS: A CASE STUDY OF CHASHMA SUGER MILLS, D.I KHAN

Liaqat Ali Khan
Civil Engineering Department, UET Peshawar Campus iii, liaqat0501@gmail.com

Abstract - Sustainability is one of the most important concerns of the world today. The concept of sustainable development is gaining popularity of all around the world in day by day in economic sector like construction, architecture, agriculture, water resource & public health engineering. Water is life of all human activities so sustainable usage of water is very critical. Waste water generate from industries are to be reuse in other purposes to maintain circular economy. To reserve natural resources, reduce, reuse and recycling of waste water are very important. This research is about Industrial waste water analysis of Sugar Mills. The waste water generating form various processing units of the mill are discharged into a nearby canal. The water of this canal is further used for various purposes of economy and social purposes e.g. for agriculture, drinking (animals), construction and by other aquatic life. The purpose of the research is to analyze this waste water to know whether it is hazardous or advantageous for above social and economic activities. Un-treated sewage is also responsible for contaminating of environment with harmful micro-organisms called pathogenic bacteria. This pathogenic bacterium causes serious diseases like cholera, typhoid, dysentery, dangi etc. Also the floating sewage of untreated sewage decomposes & creates unpleasant smell & odors in waste water. Grab samples of water were together from all the units and particular areas at regular intervals inside Mills. They were analyzed for physical perimeters (color, taste, odor, turbidity, Total dissolved solid), chemical parameters (Hardness, chlorides, alkalinity, PH values) and for Biological perimeters (COD, BOD). We compare the results of physicals, chemicals and biological tests with the environmental standards CFWQG and NEQS. Some of the results are within range but some are positive. It is recommended that appropriate water treatment system is to be planned to treat the waste water before entering to the canal or river to make the environment free from pollution.

Keywords- Sustainability, water quality, public health, social well-being, circular economy, Chashma sugar Mills D.I khan.

1 INTRODUCTION

1.1 Project Purpose

The concept of sustainable development is increasing day by day in all areas of economic sector like construction, architecture, agriculture, water resource & public health engineering. Water is life of all human activities so sustainable usage of water is very critical. Waste water generate from industries are to be reuse in other purposes to maintain circular economy. To reserve natural resources, reuse and recycling of waste water are very important. The current research is about waste water analysis of "Chashma sugar Mill D.I khan" to protect the environment from negative impact & reuse the waste water as circular economy and for social well-being. Grab samples were collected from various units of mill discharging waste at regular interval. These samples, composed periodically, were inspected in environmental lab for physical, chemical and bacteriological analysis/aspects. The tests conducted were turbidity, alkalinity, TDS, Hardness, Chlorides content, PH, Alkalinity, COD and BOD. The results so obtained from these tests were compared with NEQS (National Environmental Quality Standards) and CFWQG (Canadian Federation waste water Quality Guidelines), and suggestions/recommendations were made accordingly. There are some factors which are necessary to study & also adopt a necessary actions to control their negative impacts on environment, social and economic pillar of sustainability. i) The floating sewage of untreated water decomposes & creates unpleasant smell & odors in waste water. ii) The large Amount of organic matter present in un-treated water starts consuming the dissolved oxygen. Due to less amount of oxygen in water fish start dying, so determining of BOD & COD is prime important. The emitted CO2 may also causes to increasing the carbon foot print & effect the environment. iii) Untreated sewage is also responsible for contaminating the source water with harmful micro-organisms called pathogenic bacteria. This pathogenic bacteria causes serious diseases like cholera, typhoid, dysentery, dingy etc.

iv) These water may further uses for animal drinking. It create stomach problem & affect the digestion process in case of larger alkalis. v) Depletion of oxygen causes death of aquatic life which affects the social human attraction. vi) Hard water may cause washing & cleaning problem by more soap consumption. vii) The canal water may further use for local construction e.g. brick masonry, plastering, curing etc. viii) Use for agriculture purposes as good fertilizer [1] [2] [3]. Keeping in view the highly contaminated nature of waste water discharged from sugar industries and its consequent toxic effects on human health, domestic animals, aquatic life, construction and agricultural crops, current studies were performed to overview the strategies used for the treatment of waste water of sugar industries.

1.2 Brief History Of Chashma Sugar Mills, Geology And Hydrology

Sugar is extensively utilized in everyday human life as a basic source of sweeteners, preservatives and energy. To conduct water analysis study, a brief historic background, current status and expected new direction in the study area are required. In our country there are 78 sugar mills, out of which 40 are in Punjab, 32 in Sindh & 6 in KPK. Its total installment capacity of sugar production is 5 million tons. The Chashma sugar mill is one of the oldest mill in Pakistan. It is spread over an area of 1200 canals. It is situated on Multan road in district DI KHAN and have an easy access to the market. Its daily production is 4000 Bags per day. The waste water discharge from various units of mill is found to be ½ cusecs or 0.535 mgd. The mill and all around area consist of alluvial soil along with clay and to some extent the mix also contain sand. The water level is generally low and the water requirements for the various units are accomplished by tube wells installed inside the mill. The waste water generated from mill is discharged to a nearby canal.

The major raw material for production of sugar and gur are the sugar crop. It is cash crops having main economy of our country depend on a value of 6.7 & 1.7 in agriculture and GDP respectively. Sugarcane is one of the main source of founding sucrose. For extracting the most purest sucrose among all the raw material, there will require some chemicals in refinery which ultimately causes wasted water. In 1st step Ca(OH)2 which are produced by conversion of CaCO3 to CaO or by direct from CaO are to be uses in initial clarification known as defecation. It is necessary to coagulate all the precipitated impurities as insoluble mass which can be easily separated. Second step is carbonation in which CO2 from wet scrubbing unit of boiler or from calcination of lime kiln is bubbled through the liquid for precipitated the remain impurities. In third step of clarification phosphoric acid is added with sugar mixture for remove impurities. In sulphitation process the melt sugar are treated with SO2 for decolonization which is obtain through burning of sulphar in rotary kiln. Polyelectrolytes are further mix up with solution to coagulate the impurities separated during defection and clarification. Furthermost lead sub acetate a toxic chemical are used for analyze the sugar content.

A symbiotic frame work is established which contains the by-products of sugar industry and works as source of energy manufacture and sustainable building material [4]. There are some major by-product obtain during sugar production process like bagasse, mud or filter cake & molasses. Bagasse are the residue of sugarcane fiber which are 30% of total sugar constituent. Baggage contain approximately 50% of moisture. It is used as fuel in the mills up to 90% heating the boilers. Bagasse also used in paper making and production of pulp. Mud or filter cake are solid precipitate accumulated in base of vacuum chamber after result of clarification and carbonation process. Mud obtained by the process of sulphitation and carbonation are 3% and 7% of cane respectively. Mud generate from sulphitation are mainly use for fertilizer but their disposal creates some serious problem. Often it can be dump in low lying areas. The third by-product obtain from sugarcane industry are molasses which is about 4.85% of sugarcane amount. It is uses for sweetener for cattle feed and for produce industrial alcohol.

1.3 Need Of Work:

Sugar industries release a variety of contaminants which are toxic for the environment [5]. The production of sugar from sugar cane brings about alarming environmental changes due to extraordinary water usage and greater chances of eutrophication [6] [7]. Increasing numbers of deaths of domestic animals have also been reported due to this polluted water [8]. Sugar mills play a central role in water, land and air pollution [9]. The untreated sugar industry effluent contains high amounts of COD, BOD, TSS, TDS, and low contents of DO. Hence the effluents characteristics need to be properly monitored for better environmental protection and without proper treatment it is not directly dispose into canal that effect surface water body, pollute ground water & agriculture land [10]. Sugar industry effluent (SIE) is characterized as high organic load [11]. The waste water discharged from mill through open channel (drain) into a nearby canal. This canal water is used for agricultural and for other usual purposes like animal drinking, and masonry works of construction etc. As for sugar production various chemicals are used, which are either toxic or non-toxic. These chemicals also discharged with the waste water into the canal. Some undesirable characteristics of waste water are:

- Some organic matter soluble in canal water may seriously causes depletion of oxygen.
- Trace organics and phenols causes tastes and odors.
- Heavy metals, cyanides and toxic substances are harmful to living groups.
- Color and turbidity create unaesthetic conditions in water bodies. As a result, oxygen availability and photo synthesis are also affected. Suspended solids impair normal aquatic life
- Oil and floating matter return to reaeration.
- Hot water discharges from factories act on solubility and affect bacteriological action.
- Acids and alkalis affect aquatic life.
- Inorganic material may give rise to various problems such as hardness and corrosion.

2 RESEARCH METHODOLOGY

The common parameters are presented for analysis so as to understand the basic procedures. Generally, physic-chemical and biological treatments are used to treat the sugar industry wastewaters [12].

2.1 *Physical Perimeters*

Physical parameters may be turbidity and total dissolved solids. **Turbidity** is the quantity of occupancy of colloidal particles. It may due to silt, clay and presence of microorganism. The amount of turbidity depends upon the type of soil over which this water has run and the velocity of water. **TDS** are the mixture of all organic and inorganic substances which are present in a molecular, ionized or micro-granular suspended form contained in a liquid.

2.2 *CHEMICAL PERIMETERS*

The chemical parameters to be analyzed are pH, Alkalinity, Hardness, Chlorides.

PH is defined as the logarithm of the reciprocal of the hydrogen ion concentration expressed in moles / liters. More simple, the pH value of water sample expresses its tendency to accept or donate Hydrogen ion on a scale of 0 (very acidic)-14 (very basic) and 7 (neutral or mineral water). The pH value represents the instantaneous hydrogen ion concentration rather than the buffering capacity or the total reserved as an acidity and alkalinity test. **Hardness** in water is the presence of multivalent cations that cause to form scales and resistance to soap. It has two types i.e. temporary hardness and permanent hardness. **Alkalinity** raises to the competency of water to neutralize acids. In the waste water the most common cause of alkalinity are due to presence of carbonates, bicarbonates and hydroxide. The type and level of alkalinity are directly consequence on the source of industrial waste water. A high level of alkalinity indicates the presence of strongly alkaline industrial waste. **Chloride** has a number of commercial and industrial applications and is used in the form of sodium chloride (NaCl) and calcium chloride ($CaCl_2$) are extensively used in industries. It is available in ionic and molecular form in waste water depending on the discharging unit.

2.3 *Biological Perimeters*

These paremeters are Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD).

COD is the amount of oxygen required by the strong oxidizing agent to completely oxidize the organic matter under acidic conditions. The BOD, the organic matter is not completely oxidized. Biologically degradable organic matter is only oxidized. But in COD both the bio-logically degradable and biologically inactive organic matter is oxidized, so COD is always more than BOD. **BOD** is the oxygen amount required for the microorganism (bacteria) existing in the waste water to convert the organic substance to stable inorganic compounds i.e. H2O and CO2. Its determination is very much important because it will give you the oxygen consumed. So if it is more it will have adverse effects on the aquatic life. i.e. Organic Substance + Oxygen +Bacteria ---------→ CO2 + H2O

2.4 Sampling

Sampling means collecting a representative portion of waste water from an area to ascertain its quality and characteristics. Waste water samples may be taken from treatment plants, disposal sites and in polluted rivers or soils. Grab samples were taken for analysis from the following selected localities of mill; i) Mill Water ii) Injection Water iii) Feed Water. ***Mill Water*** is coming from crushing unit of the Mill. It is that water which has been used in removing mud and clay attached to sugar cane also carrying oil and grease. It is usually sprinkled over the sugar cane in crushing plant. ***Injection water*** is used for cooling of boilers and after two or three cycles when it becomes dirty and hot, is discharged to the main drain of Mill. During circulation through boilers in pipes, it gets polluted due to leaching and corrosion of pipes. ***Feed water*** is mixture of distilled water in combination with various chemicals like NaCl and NaOH etc, used for purification purpose. All the drains carrying these three types of water, combined together in a single drain leading to the nearby canal.

Sampling is one of the most basic & very important phase/aspect for analysis of waste water. The significance of waste water analysis mostly depends on sampling procedure. Samples should be collected sensibly for analysis to make sure that the most representative model is obtained. As possible to minimize the effects of drainage system the samples should be taken as closely to source of discharge. The sample container should be filled slowly, to avoid air bubbles. Generally as little time as possible should elapse between collecting the sample and making analysis. Depending on the nature of test, special precautionary measures in handling the sample also may be necessary to prevent natural interference such as organic growth or loss or gain of dissolved gases. Waste water samples are taken in glass bottles or in plastic bottles pre-cleaned with vim or washed many times with tape water, dipped with HCl (conc.) and again washed with tape water and finally with distilled water before the bottles were dried. Different sampling procedures were employed for different types of water and all necessary precautions were taken. To obtain an accurate results the samples should be analyzed on the same day.

Figure 1: Feed water sprinkling in Mill

Figure 2: Injecting water for cooling in atmosphere

Figure 3: Mill water discharging from Mill

Figure 4: Combine (Feed + Mill + Injecting) water discharging from Mill

2.5 Experimental Testing:

a) Physical test (Turbidity & Total Dissolved solid)

b) Chemical test (PH, Hardness, Alkalinity, Chlorides)

c) Biological test (BOD and COD)

3 RESULTS & FINDINGS

In this chapter we compare the results of each parameter with international Canadian Federation Waste Water Quality Guidelines (CFWQG) and also with National Environmental Quality Standards (NEQS) of Pakistan.

3.1 Physical Parameters

Turbidity level of waste water of Chashma Sugar Mill is presented in Table 1. Its value is maximum for mill water i.e. 106 NTU and minimum for feed water i.e. 12.8 NTU, and the combined average result of all the three samples is within the range of both NEQS and CFWQG standard. If the value is not in standard range it will affect the process of photosynthesis (plants, algae & bacteria). The value of this TDS is listed in table 2. The value was found to be maximum for mill water i.e. 800 mg/lit and minimum for Feed water i.e. 340 mg/lit. The average result is 535 mg/lit which lies under the range of both standards. The higher value cause the following affects.

- Dissolved solids forming a scum on the water surface affecting reaeration.
- Oil and grease also clog and interfere in treatment units.

Table 1-Result of Turbidity test

Sample	Turbidity (NTU)	Combine drain (NTU)	CFWWQG (NTU)	NEQS
Feed water	12.8			
Mill water	106	71.9	20-140	15-2000
Injection water	97			

Table 2-Result of Total dissolved solid (TDS) test

Sample	TDS (mg/lit)	Combine drain (mg/lit)	CFWWQG (mg/lit)	NEQS (mg/lit)

Feed water	340			
Mill water	800	535	1500-2000	3500
Injection water	465			

3.2 Chemicals Parameters

The PH values of different samples are written in table 3. The maximum value was 9.16 for Feed water and 7.06 for mill water. The average value lies within the range of mentioned guidelines. pH is important parameter to be found for waste water due to corrosion control, biological process , seal formation in boilers, disinfection and Chemical coagulation . In Table 4 the total Hardness values of the samples are found to be maximum for Mill water i.e. 480 mg/lit as CaCO3 and minimum for Feed water i.e. 160 mg/lit as CaCO3. Hardness of all the samples examined and was found well within acceptable level of NEQS but don't satisfy CFWQG standards. Higher values will cause scale formation in hot water boilers and also effect skin. The Alkalinity value is found in table 5 & its maximum value for Feed water i.e. 260 mg/lit and minimum for Injection water i.e. 180 mg/lit. The average result (220 mg/lit) is out of range of both NEQS (200 mg/lit). Alkalinity value in standard range is required for proper chemical reaction in WWTP and having same effects like acids. The values of different chloride samples are written in table 6. The maximum value is found 675.11 mg/lit for Mill water & minimum for Feed water which is 410.94 mg/lit. The avg: result is 538.13 mg/lit which is in well accepted range of NEQS i.e. 1000 mg/lit. If it exceeds the standard value, causes corrosion of various metals used in water handling systems.

Table 3-Result of PH test

Sample	**PH**	**Combine drain**	**CFWWQG**	**NEQS**
Feed water	9.16			
Mill water	7.06	7.87	6-9	6-10
Injection water	7.41			

Table 4-Result of Hardness test

Sample	**Hardness (mg/lit)**	**Combine drain (mg/lit)**	**CFWWQG (mg/lit)**	**NEQS (mg/lit)**
Feed water	160			
Mill water	480	346.76	112-152	368-1050
Injection water	400			

Table 5-Result of Alkalinity test

Sample	**Alkalinity (mg/lit)**	**Combine drain (mg/lit)**	**CFWWQG (mg/lit)**	**NEQS (mg/lit)**
Feed water	260			
Mill water	220	220	NA	200
Injection water	180			

Table 6-Result of Chlorides test

Sample	**Chlorides (mg/lit)**	**Combine drain (mg/lit)**	**CFWWQG (mg/lit)**	**NEQS (mg/lit)**
Feed water	410.94			

Mill water	675.11	538.13	NA	1000
Injection water	528.35			

3.3 *Biological Parameters*

The COD value is found maximum for Injection i.e. 184 mg/lit and minimum for Feed water i.e. 143mg/lit in table 7. The average result (165.66 mg/lit) is out of range of both NEQS (150 mg/lit) and CFWQG (80mg/lit), its excess will cause more oxygen consumption and will cause danger for aquatic life. Hence proper treatment must be done to bring it with in the permissible limits. The BOD value is found maximum for Mill water i.e. 152 mg/lit and minimum for Feed water i.e. 70 mg/lit in table 8. The average result (112.33 mg/lit) is out of range of both NEQS (80 mg/lit) and CFWQG (20mg/lit), Hence the water must be recommended for proper treatment before being disposed into the canal.

Table 7-Result of COD test

Sample	**COD (mg/lit)**	**Combine drain (mg/lit)**	**CFWWQG (mg/lit)**	**NEQS (mg/lit)**
Feed water	143			
Mill water	170	165.66	80	150
Injection water	184			

Table 8-Result of BOD test

Sample	**BOD (mg/lit)**	**Combine drain (mg/lit)**	**CFWWQG (mg/lit)**	**NEQS (mg/lit)**
Feed water	70			
Mill water	152	112.33	20	80
Injection water	115			

4 DISCUSSION:

The reduction of 75.6% of COD and 79.2% of color content of sugar industry waste water with thermal treatment, and 97.8% of COD and 99.7% of color with combined thermal and electrocoagulation treatments under optimum conditions [13]. Sugar industry does not produce harmful chemical materials, which alter the physicochemical and biological property of the surrounding environment if proper technology can be implemented. Therefore industry is considered as a zero discharge system. The outcome of the study is that from raw to end product of sugar processes have many challenges and require proper management, otherwise causes a major effect on the environment [14]. It has been proved experimentally that adding ferric salt which works as chemical coagulant, 98% reduction in COD and 99.7% color removal in sugar waste water were noted [15].

The present research was undertaken with a view to study the extent of hazards contaminants in the waste water of chashma sugar mills. The residence of area around chashma sugar mill used this contaminated water for agriculture, animal drinking and for masonry work. The people of area are unaware whether the canal water is suitable for the above mentioned usage or not. So we planned to conduct the waste water analysis, discharging from various units of the mill, leading to the canal. For this purpose three locations in the Sugar Mill were selected which were Boilers (discharging Feed water), injection system (discharging injection water, used for cooling the boilers, circulating during the sugar processing) and from crushing plant (discharging Mill water). The parameters monitored were turbidity, TDS, PH, hardness, alkalinity, chlorides, COD and BOD. In current research work the physical aspects (Turbidity & Total dissolved solid) are found within range of CFWQG & NEQS. In chemical perimeters PH, hardness and chloride are found within standards, only alkalinity is found out of range. Biological aspects (BOD & COD) both are found out of standards.

5 CONCLUSION & RECOMENDATION

An experimental research has been conducted to know about quantitative measurement of waste water contamination of chashma sugar mills DI khan. All the physical and chemical parameters are found within the permissible range of NEQS and CFWQG guidelines values. However both the bacteriological (COD and BOD) and also one chemical (alkalinity) parameters were found in excess from standards. It is however concluded that the water used for agricultural and masonry works have no worst affect, but it is dangerous for aquatic life. Excess alkali in water causes dysentery and stomach problem for animal. Keeping in view all the results, some impotent suggestion/recommendation are made.

- Tests should be conducted on regular basis or at equal intervals so that the cause is known and remedial measures are taken.
- Local waste water treatment plants should be installed to treat the water before discharging into canal.
- Old or rusted pipes in water handling system inside the mill should be replaced by new one.
- Residents of the area should be educated to use the canal water for agricultural and other purposes.
- The use of oil and grease should be according to the requirements; otherwise skimming tanks should be used if affordable.
- Flow meter is also necessary for inlet and outlet discharge of waste water.
- Required amount of chemicals should be used for sugar processing in each unit.
- Circular economy will enable the earth for continue support human life of coming generation.

6 ACKNOWLEDGEMENT

I would like to thanks all individuals who helped me all over the research, predominantly **Engr. Prof. Dr. Majid Ali** who help me throughout publishing this research paper. I also desires to thank civil engineering department CUST Islamabad for provide ultimate opportunity & learning environment to enhance my research creativity. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] P.V. Rao, Textbook of Environmental engineering, Eastern Economy ed., PHI, 2005.

[2] E.W.S. Terence and J. Machee, Water supply and sewerage, 6th ed. McGraw hill series, 2007.

[3] R.L. Droste, Theory and practice of water and wastewater treatment, 5th ed. John Willey and sons.inc, 2009.

[4] A. Gopinath, A. Bahurudeen, S. Appari, and P. Nanthagopalan, "A circular frame work for the valorization of sugar industry wastes; Review on the industrial symbiosis between sugar, construction and energy industries," *Journal of Clean Production, vol.* 203, pp. 89-108, 2018.

[5] S. Samuel and S.M. Muthukkaruppan, "Physicochemical analysis of sugar mill effluent, contaminated soil and its effect on seed germination of Paddy (Oryza sativa L)," *International Journal of Pharmaceutical and Biological Archives, vol.* 2 (5), pp. 1469-1472, 2011.

[6] A.S. Tanksali, "Treatment of sugar industry wastewater by up flow anaerobic sludge blanket reactor," *International Journal of Chemical Technology Research*, vol. 5 (3), pp. 1246-1253, 2013.

[7] H.C.J. Franco, M.T.B. Pimenta, J.L.N. Carvalho, P.S.G. Magalhães, C.E.V. Rossell, , O.A. Braunbeck, A.C. Vitti, O.T. Kölln, and J.R. Neto, "Assessment of sugarcane trash for agronomic and energy purposes in Brazil," *Scientia Agricola, vol.*70 (5), pp. 305-312, 2013.

[8] H. Bandbafha, H. Tabatabaei, M. Aghbashlo, M. Khanali, and M.A. Demirbas, "A comprehensive review on the environmental impacts of diesel/biodiesel additives," *Energy Conversion and Management, vol.* 174, pp. 579-614, 2018.

[9] M. Aghbashlo, M. Tabatabaei, and S. Hosseinpour, "On the exergoeconomic and exergoenvironmental evaluation and optimization of biodiesel synthesis from waste cooking oil (WCO) using a low power, high frequency ultrasonic reactor," *Energy Conversion and Management., vol.* 164, pp. 385-398, 2018.

[10] A. Panhawari, K. Faryal, A. Kandhoro, S. Qaiseri, T. Naveedi, and N. Memoni, "Assessment of waste water quality of selected sugar mill in Pakistan," *Global Scientific Journals*, vol. 7, pp. 1100-1118, 2019.

[11] C. Sharma and V. Kumar, "Analysis of the Volume of the Main Water and Wastewater in a Sugar Manufacturing Process Followed by the Suggestion regarding the Reutilization of the Waste Water," *International Journal of Current Engineering and Technology*, vol. 5 (3), pp. 01–05, 2015.

[12] S. Gondudey and P.K. Chaudhari, "Treatment of Sugar Industry Effluent through SBR followed by Electrocoagulation," *Sugar Tech, vol. 22, pp. 303-310, 2020.*

[13] O. Sahu, D.G. Rao, A. Thangavel, and S. Ponnappan, "Treatment of sugar industry waste water using a combination of thermal and electrocoagulation process," *International journal of sustainable Engineering*, vol. 11, pp. 16-25, 2018.

[14] O. Sahu, "Assessment of sugarcane industry: suitability for production, consumption, and utilization," *Annals of Agrarian Science*, vol. 16, pp. 389-395, 2018.

[15] O. Sahu, "Electro-oxidation and chemical oxidation treatment of sugar industry wastewater with ferrous material, an investigation of physicochemical characteristic of sludge," *South African Journal of Chemical Engineering, vol.* 28, pp. 27-29, 2019.

PHYSICOCHEMICAL AND BIOLOGICAL ASSESSMENT OF POTABLE WATER OF SAHIWAL CITY

[a] Syeda Aqsa Gillani, [b] Asim Qayyum Butt, [c] Faraz ul Haq
a: CED, QCE&T Sahiwal, gillani.syeda111@gmail.com
b: CED, QCE&T Sahiwal,asimbutt7891@gmail.com
c: CEWRE, UET Lahore, engrfaraz@uet.edu.pk.com

Abstract: - Water is one of the essential necessities among all and used for various purposes from human consumption to industrial use. Over 70% above, of the Earth's surface, comprises of water, only less than 1% of which is available as freshwater. Approximately more than one billion people lack safe drinking water worldwide. This paper studies the physicochemical and biological contamination in potable water of Sahiwal, for exactness of their influence on water quality. For this purpose, the bore and municipal water samples were collected from 6 different localities of the city. They were analyzed for 11 parameters including, temperature recorded by the ordinary thermometer, taste, color and odor were detected by six senses, the value of pH and total dissolved solids (TDS) with the help of pH meter and TDS meter, turbidity by using nephelometer, total hardness, alkalinity and dissolved oxygen (DO) by the titration method. This qualitative analysis strategy adopted to undertake this research has provided valuable data and information. For all the samples, the degree of temperature and measure of color, taste and odor were unobjectionable. The amount of turbidity, alkalinity and hardness were satisfactory. The amount of pH also lies within the permissible ranges set by PS: 1932-2010, WHO and IS: (10500-2004) standards. The amount of TDS was also in between excellent to the fair ranges. However, the amount of DO in municipal water samples of Shadman Town and Sadman Town and bore water of Johar Town and Sadman Town samples was found less than the required limit set by the WHO. The research signifies that overall, the water quality of all the samples was fit for the drinking purpose and can be utilized for various domestic purposes without any reluctance or second thoughts. The results of this study can enhance the understanding of quality of safe drinking water in Sahiwal.

Keywords: - Assessment, Alkalinity, Acidity, Potable water, Dissolved Oxygen, Physicochemical, Total Dissolved Solids

1 INTRODUCTION

Approximately more than one billion people lack safe drinking water worldwide. In developing countries, approximate 50% of the water used, is obtained from boreholes and wells, and more than 1000 million people in Asia depend upon these resources. Many analytical methods are used to check the presence and concentration of harmful material in water. Most of the health issues related to water are the result of biochemical contamination present in it. In addition to the dangerous problems of water pollution in developing countries, the water caused deaths and diseases are also an important issue worldwide. Drinking water is the cause of a large number of deaths in Pakistan too. As per the conducted survey, polluted water is one of the main threats to people's fitness in Pakistan that kills about 100,000 people a year, and over 250,000 children every year. In 2015, in Pakistan, 311189 people were died because of polluted water consumption [1], and in 2018, 40% of deaths were caused by it [2].

Pakistan falls on number 80 in the list of 122 those states which consume contaminated potable water. The water quality in several cities of Pakistan is deteriorating day by day due to uncontrolled municipal and industrial wastewater control and excessive use of fertilizers and pesticides [3]. So, large-scale water assessment is the need of the hour to evaluate and treat drinking water in Pakistan that will help to produce water that is safe and palatable. This research is mainly based, on qualitative analysis potable of water in Sahiwal, the city of Punjab, Pakistan. This city is also one of the main cities in Punjab, Pakistan. As a district, it has a population of 2,517,560, of which 419000 are in urban areas

[4], [5]. Although Sahiwal division is mainly comprised of villages, its literacy rate is relatively high compared to many other regions of Punjab, because of the importance of this city, it is essential to access and monitors the quality of its potable water, as there are no initial reports or in-depth research available related to ground and municipal water quality assessment of this city. The innovation of this research was particularly concerned about the collection of water samples, to test physicochemical and biological contamination present in the fresh potable water of Sahiwal city, for exactness of their impact on the quality of water. This qualitative analysis strategy adopted to undertake this research has provided valuable data and information. The results of this study can enhance the understanding of quality of safe drinking water in Sahiwal. For the study, time and resources were the major constraints, which limited the scope of the research within academic limits only. Moreover, the collage lab was not well equipped. So, some chemicals were brought on order, which took much of the time and cost. Some of the tests were skipped because of non-availability of required chemicals in Pakistan. The adopted methodology and the obtained results can be replicated in other cities of Pakistan and where considerable issues of potable water contamination are being rising and the availability of the resources are limited.

Many studies have been, presented at the research level on the qualitative assessment of water, which will make public the consequence of this purposed research. In 2020 the research was conducted to check the physical (pH, EC, TDS, total hardness, turbidity) and chemical (Ca, NO_3, K, Fe, Zn, SO_4, Na, Mg, HCO_3, Cl) parameters of bore water samples collected at the depth of 100 and 150ft from the Sindh Industrial and Trading Estate (SITE) zone of Karachi and it was observed that all the parameters other than the pH of the samples were above the requirements of WHO and Pakistani standards of water quality [6].

In 2013, in district Mardan Khyber Pakhtunkhwa, Pakistan, various physicochemical parameters odor, taste, temperature, color, alkalinity, total hardness pH, TDS, EC, HCO_3, Mg, Ca and turbidity, were investigated for 39 potable water samples gathered from groundwater source of 13 union councils. The results showed that the taste of 23%, TDS of 15% samples, EC of 38% samples and the hardness of 20% of samples, were out of the ranges set by the Pakistani Standards of water and WHO, [7]. In India, the drinking water quality of many lakes were evaluated, for physicochemical and biological parameters, i.e. Total Hardness, TDS, DO, Specific Conductance, COD, pH, DO, temperature, TS, and Total Alkalinity by the standard methods. The results for many lakes in Nagpur city, Gorewada lake and various other lakes revealed that the majority of the parameters were significantly dominant, in the summer as compared to the winter [8], [9],[10].

Farzaneh [11], in 2019, checked the microbial and physical quality of potable water of Maku city (Iran) and, also determined the spatial distribution of chemical quality parameters of potable water through GIS during summer and winter. The research conducted for two years showed, all the parameters under consideration for 136 samples from 36 distribution networks during summer and winter were, within the standard ranges of WHO and Iranian National Standard, and overall, water was good and safe for drinking. In Bahr Dar city (Ethiopia) microbiological study, i.e. total coliform and faecal coliform by membrane filtration technique and physicochemical study, i.e. turbidity, EC, nitrate, TDS, pH, sulphate, temperature, free residual chlorine, phosphate, iron and manganese by thermometer, EC meter, pH meter, TDS meter, turbidity meter and by standard methods of APHA was conducted to check the water quality. It was found that TC and FC bacteria were detected in all the tap water samples [12].

Various biochemical and physical parameters were analyzed for one year, before and after the monsoon season, for different potable water samples of city Bhopal, India. From the results, it was observed that most of the parameters, including pH, electrical conductivity, Cl^-, alkalinity, total hardness, calcium hardness, magnesium hardness, dissolved oxygen, chemical oxygen demand were, within the prescribed range, of IS: 10500 while others such as free carbon dioxide, biochemical oxygen demand were out of the range of ISI and WHO [13].

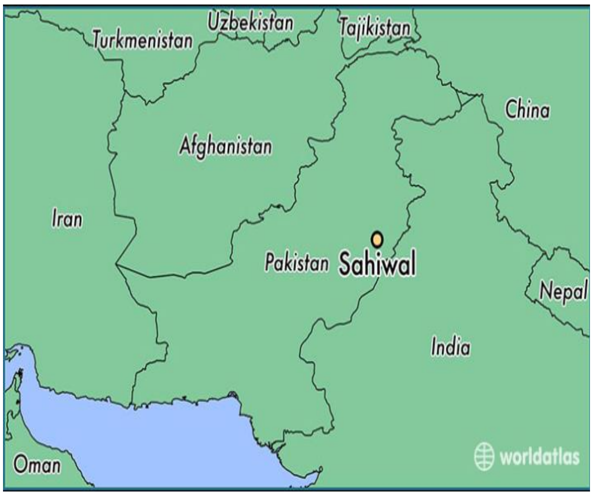
The physiochemical study conducted in different commercial and residential areas of Perak state Malaysia revealed that the overall water was safe for potable water supply with the values of all the parameters within the required limits of NDWQS and WHO [14]. The research was aimed to analyze the different water quality parameters in Manchar Lake Sindh, Pakistan during 2005-2007, (Ni, Zn, Cr, Pb, Se, Mg, Mn, Fe, total alkalinity, K^+, Ca^{+2}, EC, Cd, Cu, pH, Cl^-, PO_4^{-3}, SO_4^{-2}, Co and As) and it was observed that other than, carbon monoxide, chromium, copper and manganese, all other elements were more than required limits, compared with WHO standards [15].

Devendra [16], measured the various biological and physicochemical parameters, to assess the bore water quality of various wards of Indore city India and the parameters analyzed from November to February and March to May include (1)Total alkalinity, (2)Temperature, (3)pH, (4)Total hardness, (5) TDS, (6)Chloride, (7)Turbidity and(8) COD. After comparing the obtained result with the Indian Standard of Drinking Water Standards, (IS 10500-2012) it was observed, that during the wet season, the majority of the parameters of water quality were higher up to some extent than in the dry time of year. The research was conducted, in University of Punjab at Lahore (Pakistan) to determine the chemical, physical and biological contamination present in water samples.

The studies showed that the amount of all the under-consideration parameters was above the WHO standards. The overall, water quality was not good [17]. The study was, conducted in Nekemte Oromia (Ethiopia) to check the bacteriological, chemical and physical quality of untreated, primary distribution sources and residential tape water in the dry season for the one year. The outcomes revealed that for most of the samples, all the parameters were as per within the World Health Organization and Ethiopian Drinking Water Standards, but some of them were more than the range. It was concluded that bacteriological contamination was present in both sources of drinking water [18]. In 2013, at Sargodha city, (Pakistan) for one-month June-July, the groundwater quality assessment was done, to check the physicochemical parameters including; pH, EC and TDS. It was, concluded that the amount of the parameters was more than the WHO prescribed limits. Hence the water was substandard and not safe from a drinking point of view [19]. The drinking water quality near and surrounding the municipal solid waste dumping areas in Jhang city, Pakistan was assessed in 2018, for the various physicochemical parameters. It was noticed that TDS was high (75%), CE (90%), Cl^- (35%), Hardness (60%), Alkalinity (25%) and calcium (30%) respectively. The water condition in controlled area was much stable and 90% of samples results were in limits as per WHO purposed values of parameters [20]. The chemical, biological and physical water quality tests performed on the water samples of Islamabad showed that alkalinity, hardness, and TDS in all the samples were within the range set by the Pakistan Standard and Quality Control Authority (PSQCA). However, coliform and E. coli bacteria were found in all samples. The water was suggested not fit for drinking purposes as per WHO recommendations. A large amount of calcium, limestone, and magnesium carbonate in potable water caused a critical degree of hardness in I-9 and G-10 parts, in Islamabad [21],[22].

2 METHODOLOGY

Water pollution is a severe worldwide issue which demands unending analysis and modification of water resource policy at all levels. In Pakistan, city Sahiwal (30.6682° N, 73.1114° E) is the administrative center of District and Division Sahiwal in Punjab, with a population of 1,843,194 people. For the water quality assessment bore and municipal samples were collected from 6 different sites that were Farid Town (30.6722°N, 73.0789° E), Sadman Town (30.6654°N, 73.1088°E), Canal Colony (30.6706°N, 73.0981°E), Staff Colony (30.66663°N, 73.0946°E), Shadman Town(30.6878°N, 73.1010°E), and Johar Town (30.6586°N, 73.128°E) Sahiwal.

a.


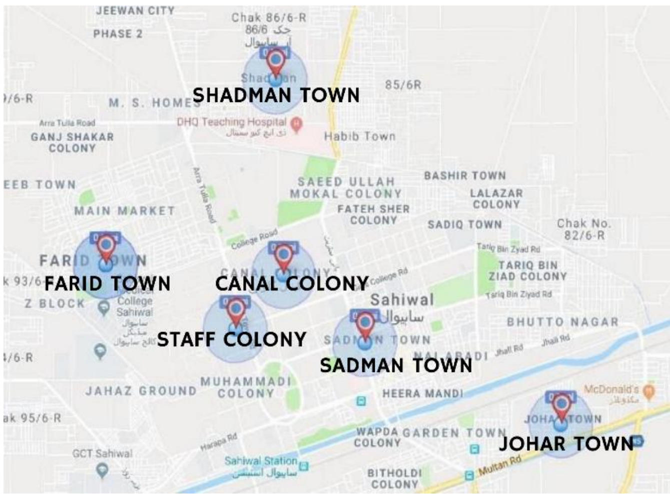
b.


Figure 1: a, Location, Sahiwal city, and b, selected sites of a city

The framework of methodology adopted during the research work is as follows;

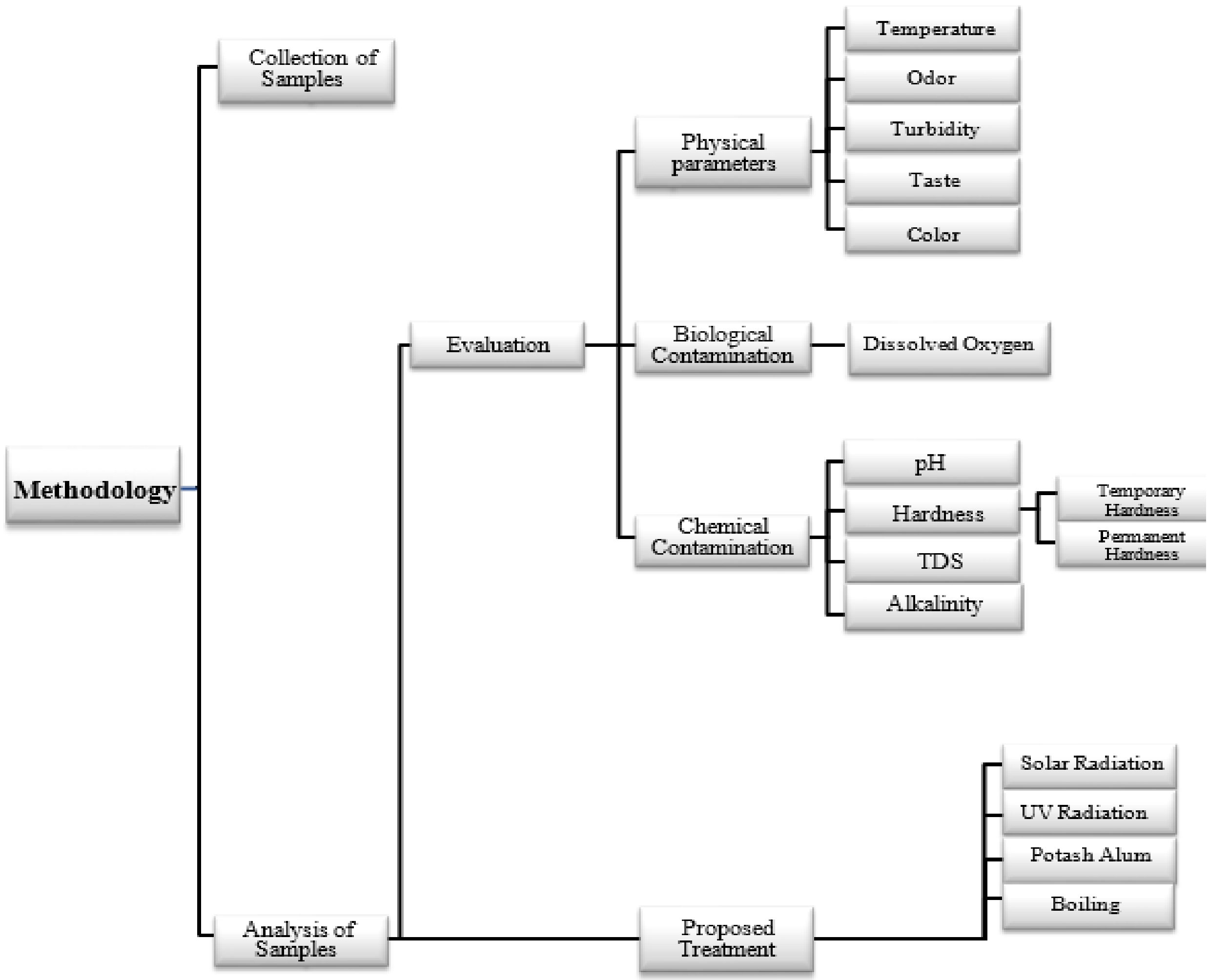


Figure 2: Framework of Methodology

Total of eleven parameters was considered such as temperature, taste, odour, colour, turbidity, pH, alkalinity, TDS, total hardness and DO for analysis of water samples. The apparatus used were a thermometer, nephelometer, burette, flak, measuring cylinder, stirrer, pipette, pH and TDS meter. The procedure adopted was as follows, the temperature of the water samples was recorded by the ordinary thermometer. The odour, colour and taste were tested by smelling, visualizing and by drinking the water samples respectively. The pH value was noted by placing the pH meter into the specimens. The turbidity of the samples was checked by nephelometer with a nephelometric tube inside, filled with the water sample. The amount of scattering of light gives the measure of turbidity present in a sample. The amount of Total Hardness, Alkalinity and Dissolved Oxygen (DO) were investigated in water samples by the titration method. The difference between the initial and the final reading of the burette filled with the standard solutions gives the amount of that particular parameter present in water samples. In the case of Total Hardness, the titrant used was sodium salt of EDTA with the blue colour representing the endpoint of the titration. For alkalinity test, the standard solution was sulphuric acid and the endpoint light orange colour. For checking, the DO of the water samples, sodium thiosulphate was used as a titrant, and the endpoint was yellow. The number of TDS present in water was counted simply by dipping the TDS meter into the water sample. The beneficial and reliable methods for the elimination of water contaminations (if present, in any season), were also suggested that can be adapted efficiently by the people at the domestic level. The purposed methods for the treatment of the water samples include boiling, UV radiations, solar radiations and by using potash alum.

3 Analysis And Results

The integral role of water depends on the quality of the water. According to the research, carried out with the analysis of the Sahiwal areas, the results were monitored for water quality assessment. A total of twelve samples were collected from six distinct areas. A brief overview of the state of water quality in these areas is discussed below. The required and permissible limits of different water quality parameters set by PS:1932-2010, WHO and IS (10500-2004), standards are discussed in the table1 given below.

Table 1-Permissible limits/ranges/standard set by PS: 1932-2010(R), WHO and IS: (10500-2004) For Water Quality

Parameters	**Required to Permissible Limit**		
	PS: 1932-2010	**WHO**	**IS:10500-2004**
Temperature (°C)	-	7-50	-
Taste	Acceptable	Agreeable	Agreeable
Odor	Unobjectionable	Agreeable	Agreeable
Color mg/l (cobalt scale)	5-25	15	5-25
Turbidity (NTU)	5-10	5	5-10
Dissolved Oxygen (mg/l)	-	3-9	-
Total Dissolved Solids (mg/l)	1000-1500	>600-1000	500-2000
Total Hardness(mg/L)	200-500	150-500	300-600
Alkalinity(mg/l)	400-500	500	200-600
pH	6.5-8.5	6.5-8.5	6.5-8.5

After performing the entire tests, the results were evaluated and summarized in the Table-2 given below;

Table 2-Results of Water Analysis

Site: Sahiwal City											
Longitude: 30.6682° N, Latitude: 73.1114° E											
Date of Collection of Samples: March 02, 2019											
Location	**Coordinates**	**Type Of Sample**	**Temperature (°C)**	**Color, Odor & Taste**	**Turbidity (NTU)**	**pH**	**TDS (ppm)**	**Total Hardness (mg/l)**	**Alkalinity (mg/l)**	**DO (mg/l)**	**Remarks**
Canal Colony	30.6706° N 73.0981° E	Municipal Bore	22 26	Unobjectionable	Agreeable Agreeable	8 7.5	266.5 287.25	Agreeable Agreeable	Agreeable Agreeable	3.73 6.16	Satisfactory Satisfactory
Shadman Town	30.6878° N 73.1010° E	Municipal Bore	24 27	Unobjectionable	Agreeable Agreeable	7.55 7.5	527.75 695.5	Agreeable Agreeable	Agreeable Agreeable	2.15 3.88	Satisfactory Satisfactory
Farid Town	30.6722° N 73.0789° E	Municipal Bore	25 25	Unobjectionable	Agreeable Agreeable	8 7	716.25 155.25	Agreeable Agreeable	Agreeable -	3.73 3.13	Satisfactory Satisfactory
Sadman Town	30.6654° N 73.1088° E	Municipal Bore	24 22	Unobjectionable	Agreeable Agreeable	6.55 7.28	227.5 818.25	Agreeable Agreeable	Agreeable Agreeable	2.42 2.82	Satisfactory Satisfactory
Staff Colony	30.6663° N 73.0946° E	Municipal Bore	23 23	Unobjectionable	Agreeable Agreeable	8 8.5	269 288.25	Agreeable Agreeable	Agreeable Agreeable	3.12 4.44	Satisfactory Satisfactory
Johar Town	30.6586° N 73.1283° E	Municipal Bore	26 24	Unobjectionable	Agreeable Agreeable	8 7.4	567 576	Agreeable Agreeable	Agreeable Agreeable	4.34 2.46	Satisfactory Satisfactory

4 CONCLUSION

Following conclusion can be drawn from the conducted study:

- The overall water quality of the city is satisfactory and, as such, there is no need for treatment at the initial domestic level. For all the samples, the temperature, color, taste and odor were unobjectionable. The turbidity, alkalinity and total hardness in the water was also within an acceptable value.
- The amounts of DO for some samples were somehow less than then WHO limits. The amount of pH also remained within the permissible ranges set by different standards PS: 1932-2010, WHO and IS: (10500-2004) standards. The number of TDS present in water was also lying within the excellent to the fair ranges.
- For the study, time and resources were the major constraints, which limited the scope of the research within academic limits only. Moreover, the collage lab was not well equipped. So, some chemicals were brought on order, which took much of the time and cost. Some of the tests were skipped because of non-availability of required chemicals in Pakistan.
- From, the results of the whole testing, it is concluded that there are no significant issues of any type of contamination, i.e. physical, biological and chemical present in the water of Sahiwal city and is considered as safe for drinking. The methodology adopted may also be, replicated in different cities of the country at small scale economically.
- The beneficial and reliable methods for the elimination of water contaminations (if present, in any season), were also suggested that can be adapted efficiently by the people at the domestic level. The purposed methods for the treatment of the water samples include boiling, UV radiations, solar radiations and by using potash alum.

5 ACKNOWLEDGEMENT

The author would like to thank every person who has collaborated throughout the research work, particularly Engr. Asim Quyyam Butt. The careful review and constructive suggestions by the anonymous referees are gratefully acknowledged.

6 REFERENCES

[1]. S. X. staff, “Countries with the highest pollution deaths, mortality rates,” 20-Oct-2017. [Online]. Available: https://phys.org/news/2017-10-countries-highest-pollution-deaths-mortality.html.

[2]. D. H. Nisar, "oladoc," January 2019, [Online]. Available: https://oladoc.com/health-zone/air-pollution-and-the-rising-death-rate-in-pakistan/.

[3]. 9902, T. (2013). Hydraulic structures & requirements for river dike design . Thuy Loi University, Directorate for standards, Metrology and Quality – Ministry of Science and Technology of the Socialist republic of Viet Nam.

[4]. Hengchaovanich, D. (1998). Vetiver grass for slope stabilization and erosion control with particular reference to engineering applications. Bangkok: Tech. Bull. No. 1998/2. Pacific Rim Vetiver N etwork. Office of the Royal Development Project Board.

[5]. Kasim, F., Marto, A., Othman, A. B., Bakar, I., & Othman, F. M. (2013). Simulation of safe height embankment on soft ground using plaxis. Procedia APCBEE, 5, 152-156.

[6]. Lin, H., Zhong, W., Xiong, W., & Tang, W. (2014). Slope stability analysis using limit equilibrium method in nonlinear criterion. The Scientific World, 2014, 1-7.

[7]. Tho, V. P., Luan, T. N., Xuan, H. N., & Huyen, T. N. (2018). Evaluating the impacts of flood to agriculture in Kon-Ha Thanh river basin area , Binh Dingh Province based on radar and GIS. International Symposium on Lowland Technology. Hanoi.

[8]. Ti, S. K., Huat, K. B., Noorzaei, J., & Jaafar, S. M. (2009). A review of basic soil constitutive models for geotechnical application. Electronic Journal of Geotechnical Engineering, 14, 1-18.

[9]. Wu, H., Yao, C., L. C., Miao, M., Zhong, Y. L., & Liu, T. (2020). Review of application and innovation of geotextiles in geotechnical engineering. Materials, 13(7).

[10].

[11]. D.Dohare, S.Deshpande and At.Kotiya, "Analysis of Ground Water Quality Parameters: A Review," Res. J. Engineering Sci, vol. 3, pp.26-31, 2014.

[12]. N.Shahid, Z.Zia, M.Shahid, H.F.Bakhat, S.Anwar, G.M.Shah and M.R.Ashraf, "Assessing Drinking Water Quality in Punjab, Pakistan," Pol. J. Environ. Stud. vol. 24, pp. 2597-2606, 2016.

[13]. G.Duressa, F.Assefa, and M. Jida,"Assessment of Bacteriological and Physicochemical Quality of Drinking Water from Source to Household Tap Connection in Nekemte, Oromia, Ethiopia," Journal of Environmental and Public Health, vol.2019, pp.7, 2019.

[14]. O.Riaz, T.Abbas, M.Nasar-u-Minallah, S.Rehman and Fahad Ullah, "ASSESMENT OF GROUND WATER QUALITY: A CASE STUDY IN SARGODHA CITY, PAKISTAN", j. Sci.Int (Lahore), vol. 28, pp.4715-4721, 2016.

[15]. T.Abbas, M.Fahad Ullah, O. Riaz, and T. Shehzad, "Impact of municipal solid waste on groundwater quality in Jhang City Punjab, Pakistan," J. Bio. & Env. Sci., vol. 12, pp. 134-141, 2018.

[16]. S. Mehmood, A. Ahmad, N. Khalid, Dr.A.Ahmed and T. Javed, "Drinking water quality in capital city of Pakistan," Sci Rep, vol.2, 2013.

[17]. H. Azhar, "Determination of Drinking Water Quality from Source to Consumer in Islamabad, Islamabad," Health Services Academy, Faculty of Medicine, Quaid-e-Azam University, Islamabad, Pakistan, 1996.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

DRINKING-WATER QUALITY ASSESSMENT: A CASE STUDY OF SADIQABAD CITY

[a] Faraz Ul Haq, [b] Asim Qayyum Butt, [c] Mudasser Muneer Khan [d] Syyed Adnan Raheel Shah [e] Muhammad Ahmed Qurashi, [f] Aqsa Nisar*, [g] Kazim Hussain

a:Lecturer, Centre of Excellence in Water Resources Engineering, UET Lahore , engrfaraz@uet.edu.pk

d,e,f,g Department of Civil Engineering, Pakistan Institute of Engineering & Technology, Multan.

b: Department of Civil Engineering, Quaid-E-Azam College of Engineering and Technology, Sahiwal.

c: Department of Civil Engineering, Bahauddin Zakariya University, Multan.

Abstract- Water used by humans should be fresh and non-toxic as it is one the most important need among all and used for various purposes from human consumption to industrial use. Drinking water is causing many deaths in Pakistan. Pakistan falls on number 80, in the list of 122 those states which consume contaminated potable water. The water quality in several municipalities of Pakistan is getting worse day by day. It is required to examine and analyze the quality of water in Sadiqabad, as there are no primary reports or in-depth research available related to ground and municipal water quality assessment of Sadiqabad city. This analysis was particularly concerned about the collection of water samples, to test physicochemical and biological contamination present in potable water of Sadiqabad, for exactness of their influence on water quality. For this purpose, the tube wells (bore) samples were collected from fifty-eight different localities of the city and were analyzed for 17 parameters including, Taste, Color, and Odor detected by senses, pH value by using pH meter, Total Dissolved Solids (TDS) with the help of TDS meter, Turbidity by using Nephelometer, Total Hardness, alkalinity, etc. This qualitative analysis strategy adopted to undertake this research has provided valuable data and information. For all the samples, the measure of color, taste, and odor was unobjectionable. The amount of turbidity and hardness was satisfactory. The amount of pH also lies within the permissible ranges set by WHO standards. The amount of TDS was also in between excellent to the fair ranges. It was, concluded that overall, the water quality of the city, was satisfactory and there was no need for water treatment. The results of this research can boost up the knowledge of the quality of safe drinking water in Sadiqabad. The methodology adopted can be replicated in other cities of Pakistan, where significant issues of the potable water pollution, are being risen.

Keywords- Water Quality, Potable Water, Total Dissolved Solids.

1 INTRODUCTION

Water is one of the necessities among all and used for the various purpose of human consumption to industrial use. Over 70% above, of the Earth's surface, comprises of water, only less than 1% of which is available as freshwater –not equally distributed throughout the world. Water used by humans should be fresh and non-toxic. Other than the shortage of water, there are many other incitements in providing harmless and sufficient water supply in many regions of the world. Approximately more than one billion people lack safe drinking water worldwide. A person requires to consume 2–4.5 liters of water per day for proper body functioning. Water is obtained, through underground, surface, and rain. In developing countries, approximately 50% of the water used, is obtained from boreholes and wells, and more than 1000 million people in Asia depend upon these resources. Many analytical methods are used to check the presence and concentration of harmful material in water. Most of the health issues related to water are the result of biochemical contamination present in it in addition to the dangerous problems of water pollution in developing countries, the water caused deaths and diseases are also an important issue worldwide. Approximately 500 million people are forced to use polluted water worldwide. More than 14,000 people per day, 2.2 million every year all over the developing countries die because of the unavailability of safe drinking water (Global Water Supply Sanitation Assessment, 2000; Report WHO). Drinking water is the cause of many deaths in Pakistan too. As per the conducted survey, polluted water is one of the main threats to people's fitness in Pakistan that kills about 100,000 people a year, and over 250,000 children every year. In 2015, in Pakistan, 311189 people were died because of polluted water consumption, and in 2018, 40% of deaths were caused by it. Pakistan falls on number 80 in the list of 122 those states which consume contaminated potable water. So, large-scale water assessment is the need of the hour to evaluate and treat drinking water in Pakistan that will help to produce water that is safe and palatable. The water quality in several cities of Pakistan is deteriorating day by day due to uncontrolled municipal and industrial wastewater control and excessive use of fertilizers and pesticides.

This research is mainly based, on qualitative analysis of potable water in Sadiqabad, the city of Punjab, Pakistan. This city is also one of the main cities in Punjab, Pakistan. Although the Sadiqabad Division mainly comprises villages. Its literacy rate is relatively high compared to many other regions of Punjab, because of the importance of this city, it is essential to access and monitors the quality of its potable water, as there are no primary reports or in-depth research available related to ground and municipal water quality assessment of this city. The innovation of this research was particularly concerned about the collection of water samples, to test physicochemical and biological contamination present in the freshwater of Sadiqabad city, for exactness of their impact on the quality of water. This qualitative analysis strategy adopted to undertake this research has provided valuable data and information.

2 LITERATURE REVIEW

Many studies have been, presented at the research level on the qualitative assessment of water, which will make public the consequence of this purposed research. The study about trace metals and some physicochemical properties including pH, EC, turbidity, fluoride, iron, zinc, manganese and aluminum in drinking water samples using the procedure outlined in the plainest photometer method showed that the concentrations of most of the parameters in samples were within the limits of WHO and there was no correspondence of trace metals [1]. The physicochemical study such as the temperature of air and water, pH, humidity, EC, free carbon monoxide, TS, DO, total alkalinity, TH, calcium, and magnesium, for the period of one year i.e. of water of Triveni Lake was conducted for the one year December 2010 to November 2011 and results revealed, that water was fit for drinking during winter and summer [2].In India, the various bacteriological and physicochemical parameters of water quality index (WQI) for different surface water resources were calculated especially, lakes in Nagpur city, Maharashtra (India). EC, total dissolved solids, chloride, T-H, biochemical oxygen demand, dissolved oxygen, and pH were determined by standard methods, and FC and TC were determined by Membrane Filtration (MF) technique. The results for many lakes showed, fairwater in monsoon, medium in winter, and poor quality for the summer season while, Gore Wada Lake showed moderate results for every season, other than that of monsoon season [3]. The studies reported the physicochemical properties of water such as pH, EC, turbidity, total dissolved solids, dissolved oxygen,F^-,Cl^-, $Na^+$and SO_4^{-2} in AhmedPur, District Latur and significant changes in water quality were observed, after treatment [4]. In India, the drinking water quality of many lakes was evaluated, for physicochemical and biological parameters i.e. Total Hardness, TDS, DO, Specific Conductance, COD, pH, DO, temperature, and Total Alkalinity. The result revealed that most of the parameters were significantly dominant, in the summer as compared to the winter [5]. The nearshore of Cleveland sediments of Erie Lake and Cuyahoga River, Basin were assayed with Photobacterium phosphorus during the summer, and nearly all (93%) of the "navigation channel" and the samples were toxic nearshore [6]. In Gorgan city, (Iran) the physical, microbial, and chemical properties of drinking water samples of urban areas were assessed for one year (2009-2010) and compared with national and international standards. It was, concluded that for all the 598 water samples, the chemical and physical parameters were within the standard ranges, other than that of the hardness of drinking water, which was higher than the required amount [7]. Farzaneh, Manijeh et.al. , in 2019, checked the microbial and physical quality of potable water of Maku city (Iran) and, also determined the spatial distribution of chemical quality parameters of potable water through GIS during summer and winter. The research conducted for two years showed, all the parameters under consideration for 136 samples from 36 distribution networks during summer and winter were, within the standard ranges of W.H.O and Iranian National Standard, and overall, water was good and safe for drinking [8].In Pakistan district, Mardan Khyber Pakhtunkhwa, various physicochemical parameters including magnesium (Mg), electrical conductivity (EC), odor, taste, temperature, color, alkalinity, total hardness pH, total dissolved solids (TDS), turbidity, calcium (Ca) and bicarbonate were investigated for 39 potable water samples gathered from groundwater source of 13 union councils, and the results showed that the taste of 23%, TDS of 15% samples, EC of 38% samples, and the hardness of 20% of samples, were out of the ranges set by the Pakistani Standards water and W.H.O [9]. In 2018, Mahmood et.al. analyzed the groundwater quality trend changes, in Abhar city (Iran), for 15 years and observed that first and end year of the study period, the amount of total hardness, electrical conductivity (EC), and total dissolved solids (TDS) were 606.217194.69, 192.69756.83 and 235.25784.73 464.717183.52, 744.557288.52 and 348.797106.81, respectively [10].

Devendra et.al. measured the various biological and physicochemical parameters, to assess the bore water quality of various wards of Indore city India and the parameters analyzed from November to February and March to May include (1)Calcium,(2)Sulphate,(3)Nitrate,(4)Total alkalinity, (5)Fluoride, (6)Magnesium, (7)M.P.N., (8)Electrical Conductivity, (9)Temperature,(10)pH,(11)Totalhardness,(12)TDS,(13)Chloride,(14)Turbidity,(15)Chromium,(16)Nickel,(17)Iron,(18) Cadmium, (19)Boron, (20)Phosphate,(21)C.O.D,(22)Zinc,(23)Manganese and (24) Sodium. After comparing the obtained result with the Indian Standard of Drinking Water Standards, (IS 10500-2012) it was observed, that during the wet season, the majority of the parameters of water quality were higher up to some extent than in the dry time of year [11]. Various biochemical and physical parameters were analyzed for one year, before and after the monsoon season, for different potable water samples of city Bhopal, India. From the results, it was observed that most of the parameters, including pH, electrical conductivity,Cl^-, alkalinity, total hardness, calcium hardness, magnesium hardness, dissolved oxygen, chemical oxygen demand were, within the prescribed range, of IS: 10500 while others such as free carbon dioxide, biochemical oxygen demand, NO^{-3}, F^-, and Most Probable Number tests were out of the range of ISI and WHO [12]. The physiochemical study conducted in different commercial and residential areas of Perak state Malaysia revealed that the overall water was safe for potable water supply with the values of all the parameters within the required limits of NDWQS and W.H.O [13]. The study was, conducted in Nekemte Oromia (Ethiopia) to check the bacteriological, chemical, and physical quality of untreated, main distribution sources and residential tape water in the dry season for the one year. The outcomes revealed that for most of the samples, all the parameters were as per within the World Health Organization and Ethiopian Drinking Water Standards, but some of them were more than the range. Bacteriological contamination (TC and FC), were seen in all the samples. On the other hand, in many residential water samples, they were not found FC contaminated. It was concluded that bacteriological contamination was present in both sources of drinking water [14].

3 EXPERIMENTAL PROCEDURES

In Pakistan, Sadiqabad (28.3N, 70.116667 E) is the executive tehsil of Rahim Yar Khan district in Punjab, with a population of 1.265million people shown in figure 1.

Figure 1: Study Area Map

For the water quality assessment tube, wells samples were collected from fifty-eight different station points from the whole tehsil. A total of 17 parameters was considered such as temperature, taste, odor, color, turbidity, pH, TDS, total hardness for analysis of water samples. The apparatus used were a thermometer, nephelometer, burette, flak, measuring cylinder, stirrer, pipette, pH, and TDS meter. The procedure adopted was as follows, the temperature of the water samples was recorded by the ordinary thermometer. The odor, color, and taste were tested by smelling, visualizing, and drinking the water samples, respectively. The pH value was noted by placing the pH meter into the specimens. The turbidity of the samples was checked by Nephelometer with a nephelometric tube inside, filled with the water sample. The amount of scattering of light gives the measure of turbidity present in a sample. The difference between the initial and the final reading of the burette filled with the standard solutions gives the amount of that parameter present in water samples. In the case of Total Hardness, the titrant used was sodium salt of EDTA with the blue color representing the endpoint of the titration. The number of TDS present in water was counted simply by dipping the TDS meter into the water sample. The beneficial and reliable methods for the elimination of water contaminations (if present, in any season), were also suggested that can be adapted efficiently by the people at the domestic level. The purposed methods for the treatment of the water samples include boiling, UV radiations, solar radiations, and by using potash alum. The required to permissible ranges set by, WHO are shown in Table 1 given below.

Table 1. Permissible Limits/Ranges/Standard set by WHO

Parameter	**Permissible limit**	**Parameter**	**Permissible limit**
pH	6.8-8.5	Total Alkalinity	Not Set
Colour	Un-obj	SO_4^{2}-	400 mg/l
Odor	Un-obj	Cl_2	250 mg/l
Taste	Un-obj	Iron	1.0 mg/l
Turbidity	5 NTU	Arsenic	50 ppb
Total dissolved solids	1000 mg/l	Flouride	1.5 mg/l
Ca.	200 mg/l	Total Coliform	0 cfu/100 ml
Mg.	150 mg/l	Nitrate	50mg/l
Total Hardness	500 mg/l		

4 RESEARCH METHODOLOGY

Water pollution is a serious worldwide issue that demands unending analysis and modification of water resource policy at all levels. The methodology adopted during the research work for collecting and analyzing the water samples is summarized in the form of a flowchart shown below in figure 3.

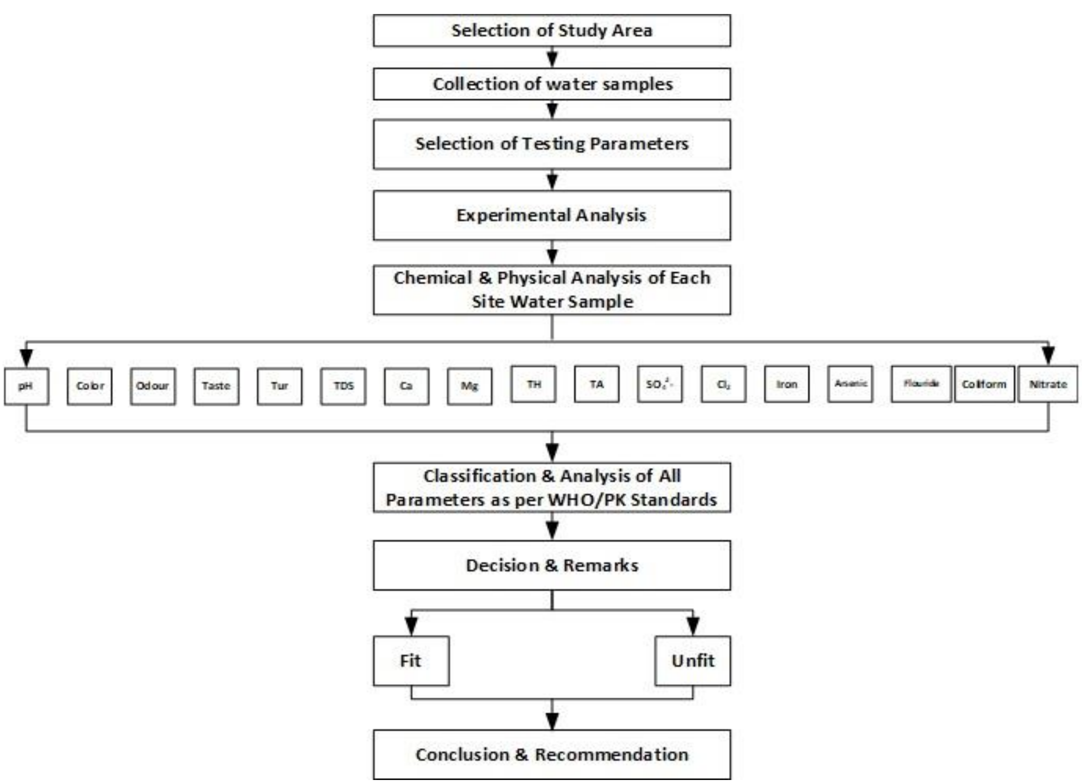


Figure 3: Research Work Methodology

5 RESULTS

The integral role of water depends on the quality of the water. According to the research, carried out with the analysis of the Sadiqabad areas the results were monitored for water quality assessment. A brief overview of the state of water quality in these areas is discussed below. The required and permissible limits of different water quality parameters set by WHO, standards are discussed in the table1 given above. After all the tests performed, the results were evaluated and summarized in table 2. A total of fifty-eight samples were collected from distinct areas.

Table 2-Water Quality Analysis of Sadiqabad City, Pakistan

Sr.No	**Location/Facility**	**pH**	**Colour**	**Odor**	**Taste**	**Tur.**	**TDS**	**Ca.**	**Mg.**	**TH**	**TA**	**SO_4^{2-}**	**Cl_2**	**Iron**	**Arsenic**	**Flouride**	**Total Coliform**	**Nitrate**	**Remarks**
1	Shahbaz pur tube well # 04	7.4	✓	✓	✓	1.47	647	50	41	213	141	140	89	3	10	1.6	0	0	Unfit
2	Shabaz pur tube well # 05	7.2	✓	✓	✓	1.68	702	77	41	241	229	190	91	3	30	1.1	0	0	Unfit
3	Shahbaz pur tube well # 06	7.4	✓	✓	✓	2.6	657	70	45	249	200	170	79	3	40	1.7	0	0	Unfit
4	Shahbaz pur tube well # 07	7.2	✓	✓	✓	1.89	637	80	37	227	237	215	77	2	40	0.74	0	0	Unfit
5	Shahbaz pur tube well # 10	7.5	✓	✓	✓	2.17	731	93	44	269	229	210	93	2	40	0.89	0	0	Unfit
6	Shahbaz pur tube well # 12	7.4	✓	✓	✓	1.71	719	101	34	237	222	200	88	2	40	0.97	0	0	Unfit
7	Shahbaz pur tube well # 14	7.2	✓	✓	✓	1.93	689	87	35	227	192	160	73	4	40	1.8	0	0	Unfit
8	Shahbaz pur tube well # 01	7.4	✓	✓	✓	1.43	670	83	37	233	207	205	82	4	40	1.7	0	0	Unfit
9	Shahbaz pur tube well # 02	7.3	✓	✓	✓	1.74	665	91	40	251	155	155	79	3	10	1.2	0	0	Unfit
10	164/p	7.3	✓	✓	✓	1.82	696	77	42	247	259	140	81	0	25	0.72	0	0	Fit
11	Ahmad pur Lamma tube well # 01	7.2	✓	✓	✓	1.39	590	77	35	217	244	150	73	0.3	30	0.68	0	0	Fit
12	Ahmad pur lamma tube well # 03	7.3	✓	✓	✓	1.82	621	73	41	239	117	121	84	0.4	10	0.76	0	0	Fit
13	Ahmad pur lamma tube well # 05	7.2	✓	✓	✓	1.69	607	59	36	205	104	105	79	0	0	0.49	0	0	Fit
14	Ahmad pur lamma tube well # 06	7.4	✓	✓	✓	2.13	623	77	39	234	259	180	84	0.6	20	0.67	0	0	Fit
15	Ahmad pur Lamma tube well # 08	7.3	✓	✓	✓	1.18	652	73	45	253	237	170	79	0	20	0.81	0	0	Fit
16	148/p	7.2	X	X	X	7.48	269	53	7	82	118	115	35	0	20	0.29	17	0	Unfit
17	146/p	7.4	X	X	X	6.89	272	47	16	110	111	95	58	0	20	0.27	20	0	Unfit
18	Basti Baiggar Garri Pumping Station	7.4	✓	✓	✓	1.33	663	133	39	289	159	166	97	0	0	0.85	0	0	Fit
19	150/p	7.1	X	X	X	5.72	311	57	15	116	133	105	39	0	20	0.21	14	0	Unfit
20	151/p	7.3	X	X	X	6.31	289	50	6	75	126	110	31	0	25	0.34	12	0	Unfit
21	RWSS 173/P	7.2	✓	✓	✓	1.62	845	101	41	267	96	80	139	0	5	0.81	0	0	Fit
22	RWSS 195 (Barra)	7.3	✓	✓	✓	2.18	306	79	9	116	97	91	46	0	0	0.63	0	0	Fit
23	RWSS 191/P	7.4	✓	✓	✓	1.89	332	73	11	116	111	50	46	0.3	5	0.64	0	0	Fit
24	RWSS 156/P	7.2	✓	✓	✓	2.13	559	33	31	158	81	55	58	0.2	0	0.51	0	0	Fit
25	RWSS 201/P	7.1	✓	✓	✓	1.89	647	53	38	205	155	95	116	0	5	0.79	0	13.29	Fit
26	RWSS 197/P	7.2	✓	✓	✓	1.79	706	67	40	226	170	100	136	0	0	0.57	0	0	Fit
27	RWSS 213/P	7.4	X	X	X	5.57	259	50	16	116	111	75	46	0	0	0.79	16	0	Unfit

28	216P	7.3	✓	✓	✓	1.37	505	109	18	181	117	125	81	0	0	0.56	11	0	Unfit
29	RWSS 211/P	7.2	✓	✓	✓	1.69	672	147	42	315	241	170	81	0	0	0.68	0	0	Fit
30	RWSS 199/P	7.3	✓	✓	✓	2.17	706	154	21	240	259	201	155	0	0	0.87	0	0	Fit
31	Pumping station 11/NP	7.2	✓	✓	✓	2.4	689	129	44	307	215	110	89	0.5	25	0.62	0	0	Fit
32	RWSS 182/P	7.3	✓	✓	✓	1.26	633	135	35	277	171	197	66	0	0	0.73	0	0	Fit
33	RWSS 86/P	7.8	✓	✓	✓	3.17	1510	207	39	363	371	509	318	0	0	0.91	0	0	Unfit
34	RWSS Walhar	7.3	✓	✓	x	1.39	1870	251	72	541	447	580	515	0	0	1.3	0	0	Unfit
35	RWSS 177/P	7.4	✓	✓	✓	1.54	805	113	45	295	222	130	120	0.4	25	0.79	0	0	Fit
36	Basti Masoorian	7.5	✓	✓	✓	3.19	882	137	74	432	133	120	97	0.8	30	0.87	0	0	Fit
37	Pumping Station Mazher Fareed colony	7.6	✓	✓	✓	1.97	669	117	50	319	207	115	75	0	0	0.75	0	0	Fit
38	Pumping Station Satellite town	7.4	✓	✓	✓	1.52	693	157	42	327	259	155	87	0	25	0.61	0	0	Fit
39	Pumping station Municipal Town	7.2	✓	✓	✓	1.31	703	161	47	349	229	145	101	0	25	0.82	7	0	Unfit
40	Pumping station near Madina cotton factory	7.3	✓	✓	✓	1.56	653	139	41	303	274	160	86	0	25	0.69	0	0	Fit
41	Pumping station Model Town	7.4	✓	✓	✓	1.43	661	129	41	294	229	135	79	0	25	0.76	0	0	Fit
42	New overhead Bridge Pumping Station	7.2	✓	✓	✓	1.61	679	153	37	301	200	105	87	0	25	0.43	0	0	Fit
43	Overhead bridge Old Pumping station	7	✓	✓	✓	1.23	688	157	38	311	192	100	98	0	55	0.86	0	0	Unfit
44	basti Moran	7.2	X	X	x	7.41	277	33	16	96	96	60	39	0	0	0.23	19	0	Unfit
45	Pumping Station Tibbi Baghawar	7.2	✓	✓	✓	1.39	663	109	45	289	252	180	76	0	10	0.58	0	0	Fit
46	RWSS 184/P	7.4	✓	✓	✓	1.93	516	87	31	212	148	70	58	0.3	0	0.53	0	0	Fit
47	RWSS 267/P	7.5	✓	✓	✓	1.41	665	92	47	281	170	115	74	2	5	0.88	0	0	Unfit
48	RWSS 161-162/P	7.3	✓	✓	✓	1.37	583	57	32	185	126	60	79	0	0	0.71	0	22	Fit
49	RWSS 185-195/P	7.1	X	X	x	4.89	256	33	14	89	74	50	43	0.3	5	0.28	9	0	Unfit
50	RWSS 189/P	7.1	✓	✓	✓	1.63	574	63	46	247	185	105	54	0	5	0.76	0	0	Fit
51	RWSS 157/P	7.8	✓	✓	✓	1.63	946	67	43	240	163	80	217	0	0	0.67	0	0	Fit
52	RWSS 194/P	7.6	✓	✓	✓	2.41	636	81	43	253	96	45	100	0	5	0.73	0	0	Fit
53	RWSS 195/P	7.2	✓	✓	✓	5.57	311	53	14	110	170	80	46	0	0	0.68	0	0	Fit
54	RWSS 160/P	7.5	✓	✓	✓	2.58	788	102	50	301	163	100	81	1.6	10	0.87	0	17.72	Unfit
55	121/p	7.2	✓	✓	✓	1.52	325	79	11	123	101	79	54	0	0	0.49	0	0	Fit
56	RWSS 175/P	7.3	✓	✓	✓	1.93	768	128	64	384	244	160	74	0	25	0.67	0	0	Fit
57	147/p	7.3	✓	✓	✓	2.85	419	77	28	191	107	111	81	0	0	0.55	0	0	Fit
58	165/P	7.6	✓	✓	✓	3.47	868	123	68	397	178	160	136	0	10	0.94	0	0	Fit

Note: ✓= Un-objectionable, x = Objectionable, Tur= Turbidity, TDS= Total dissolve solids, TH= Total hardness, TA= Total alkalinity, EC= Electrical Conductivity

Based on the results mentioned in table 2, it was, noticed that the overall water quality of the city was satisfactory and, as such, there was no need for treatment. For all the samples, the measure of temperature, color, taste, and odor was unobjectionable. The amount of turbidity, alkalinity, acidity, and hardness was also satisfactory. The amount of pH also remained within the permissible ranges set by WHO, standards. The amount of TDS was in between excellent to the fair ranges.

6 PRACTICAL IMPLEMENTATION OF WORK IN INDUSTRY

The study will be implemented to identify risky areas in the region where there is more need to install water filtration plants.

7 CONCLUSION

Over a billion people above worldwide, especially in developing countries, do not have safe drinking water. Apart from the shortage of water, there are many other challenges in providing safe, adequate, and reliable water supply in many regions of the world. The research was conducted to access different contamination found in the drinkable water of Sadiqabad for outlining their impact on water quality. This qualitative analysis strategy adopted to undertake this research has provided valuable data and information. The overall water quality of the city was satisfactory and, as such, there was no need for treatment. For all the samples, the temperature, color, taste, and odor were unobjectionable. The turbidity and total hardness in the water were also within an acceptable value. The amount of pH also remained within the permissible ranges set by different standards WHO, standards. The number of TDS present in water was also lying within the excellent to the fair ranges. From, the results of the whole testing, it was concluded that there were no significant issues of any type of contamination i.e. physical, biological, and chemical present in the water of Sadiqabad city and was considered safe for drinking. The methodology may also be, replicated in different cities of the country.

ACKNOWLEDGMENT

We acknowledge the collaboration of the Public Health Department for data collection.

REFERENCES

[1] O. Akoto and J. Adiyiah, "Chemical analysis of drinking water from some communities in the Brong Ahafo region," *International Journal of Environmental Science & Technology,* vol. 4, no. 2, pp. 211-214, 2007.

[2] R. M. Khan, M. J. Jadhav, and I. Ustad, "Physicochemical analysis of triveni lake water of Amravati district in (MS) India," *Bioscience discovery,* vol. 3, no. 1, pp. 64-66, 2012.

[3] P. Puri, M. Yenkie, S. Sangal, N. Gandhare, G. Sarote, and D. Dhanorkar, "Surface water (lakes) quality assessment in Nagpur city (India) based on water quality index (WQI)," *Rasayan journal of chemistry,* vol. 4, no. 1, pp. 43-48, 2011.

[4] S. Hussain, V. Mane, S. Takde, A. Pathan, and M. Farooqui, "Comparison between Treated and Untreated water so as to study water treatment plant of Ahmadpur dist. Latur, Maharashtra," 2011.

[5] S. Gorde and M. Jadhav, "Assessment of water quality parameters: a review," *Journal of Engineering Research and Applications,* vol. 3, no. 6, pp. 2029-2035, 2013.

[6] W. B. Arbuckle, J. H. Olive, and S. Tuckerman, "Toxicity of Cuyahoga River and nearshore Lake Erie sediments to Photobacterium phosphoreum," *Journal of Great Lakes Research,* vol. 21, no. 1, pp. 64-70, 1995.

[7] A. Bay, K. Poorshamsian, K. Karimi, M. Hashemi, and B. Maghsodlo, "Determination of bacteriological and physiochemical parameters of drinking water of Gorgan city, Iran (2010)," *Medical Laboratory Journal,* vol. 5, no. 1, pp. 13-17, 2011.

[8] F. B. Asghari, M. Pakdel, A. A. Mohammadi, and M. Yousefi, "Spatial and temporal variation of physicochemical and microbial quality of drinking water for the distribution network in Maku, Iran," *DESALINATION AND WATER TREATMENT,* vol. 142, pp. 82-89, 2019.

[9] N. Khan, S. T. Hussain, A. Saboor, N. Jamila, S. N. Khan, and K. S. Kim, "Chemical investigation of the drinking water Sources from Mardan, Khyber Pakhtunkhwa, Pakistan," *World Applied Sciences Journal,* vol. 27, no. 1, pp. 112-122, 2013.

[10] M. Yousefi, M. H. Dehghani, S. M. Nasab, V. Taghavimanesh, S. Nazmara, and A. A. Mohammadi, "Data on trend changes of drinking groundwater resources quality: a case study in Abhar," *Data in brief,* vol. 17, pp. 424-430, 2018.

[11] N. Rahmanian *et al.*, "Analysis of physiochemical parameters to evaluate the drinking water quality in the State of Perak, Malaysia," *Journal of Chemistry,* vol. 2015, 2015.

[12] D. Dohare, S. Deshpande, and A. Kotiya, "Analysis of ground water quality parameters: a Review," *Research Journal of Engineering Sciences, ISSN,* vol. 2278, p. 9472, 2014.

[13] G. Duressa, F. Assefa, and M. Jida, "Assessment of Bacteriological and Physicochemical Quality of Drinking Water from Source to Household Tap Connection in Nekemte, Oromia, Ethiopia," *Journal of environmental and public health,* vol. 2019, 2019.

[14] M. Tabor, M. Kibret, and B. Abera, "Bacteriological and physicochemical quality of drinking water and hygiene-sanitation practices of the consumers in bahir dar city, ethiopia," *Ethiopian journal of health sciences,* vol. 21, no. 1, pp. 19-26, 2011.

DIFFERENT PERSPECTIVES ON WATER QUALITY OF LOCAL FILTRATION PLANTS IN PAKISTAN

[a] Aruba Waqar, [b] Mehak Ali
a: Institute of Environmental Sciences and Engineering, National University of Science and Technology, Islamabad, Pakistan, aruba.ccrd@gmail.com
b: Department of Microbiology, Watim Medical College, Rawat, Pakistan, drmehakali15@gmail.com

Abstract- Water is very important for the survival of all living beings on earth. Water quality plays an important role for health of human beings, especially when it comes to potable water. The main sources include ground and surface waters. In this paper, a review is made on different perspectives about water quality of filtration plant for use by the common people. These include water quality importance, processes involved in filtration, different tests on quality and guidelines for safe water supply. The main aim of this literature research is to document necessities required for filtration plants for safe water so that an easy to implement ways from water supply to quality water can be proposed. Many aspects are discussed in detail to recommend some practical line of action for regulatory authorities. For efficient output, government and private organizations should work together. A proper coordination is must between regularity bodies and public.

Keywords- Water quality, filtration plant, water supply, quality tests and guidelines, regulatory authorities

1 INTRODUCTION

One of the basic necessities of life is good quality safe potable water for human beings. But, in developing countries, many people are deprived of safe drinking water, hygiene and appropriate sanitation. The powerful environmental element of health depends on the quality of drinking water and it can prevent and control waterborne diseases. The transmission of such diseases comes from many factors of faecal-oral pathways. Stored domestic water as a result of germ-infested handling, water in the distribution system, and uncleanness of potable water storage (e.g., by coliform enterobacteriacial pathogens of human or animal faeces) are few examples. The nontoxic collection, treatment, and storing potable water can be ensured using the parameters prescribed by the World Health Organization (WHO) to ensure the quality of drinking water. Those waters have no health risk which has bacteriological quality i.e. the nonappearance of gauge organisms in drinking water. Conventionally, total coliform bacteria specify the existence of faecal pollution. An exemption is Escherichia coli (E. coli), a thermo-tolerant coliform, and the utmost frequent of the total coliform group present in animal or human feces, hardly grows in the environment. Therefore, it is taken as the utmost precise indicator of faecal contamination in potable water. The existence of E. coli offers robust indication of latest faecal uncleanness. It can guess disease risk. For drinking purpose, it is mandatory that the colonies per 100 ml of coliform enterobacteriaceae Escherichia coli should be null. Guaranteeing the availability of usable potable water is an uninterrupted procedure requiring the check and balance of monitoring of many essential microbiological and physio-chemical factors. Below the earth's surface, there is groundwater which is collected in abysses of rocks and soil. It is main source of water for springs, wells and boreholes. Such water is always not safe. Worldwide, a main health alarm is from water related diseases. Every year, 1.8 million teenagers die from diarrheal diseases (i.e. one in every fifteen seconds). Globally, the utmost concerned deaths of children below five years old are from waterborne diseases. Annually, many persons die from unsafe water than from any other cause (including war).

In different countries, majority of people depend on groundwater to meet their daily requirements. Particularly, the reliable source of water supply in the arid and semi-arid regions is groundwater. But, due to population growth and global climate change, the rainfall in such regions is expected to decrease, thereby increasing the demand of groundwater. The groundwater quality and associated health risks are badly affected by both human activities and natural factors. The significant impacts are due to the land use/land cover changes. Therefore, in few cases, groundwater might be saline and not safe under extreme human activities. This can be unsuitable for direct intake and can lead to waterborne diseases to human. Nano-filtration and reverse osmosis are tertiary treatments that efficiently eliminate pharmaceuticals from effluent and drinking water. Water is utilized in numerous ways, e.g. personal and domestic hygiene, drinking, cooking, cultivation, and rituals. Organoleptic features like flavor, smell, color and core temperature are essential in the insightful detection of water quality. Water quality degradation is broadly known in many parts of the world, and establishes one of the major risks affecting human health. In addition, there are the abundant consequences of water shortage, especially of low water supplied areas of the societies. The implications of climate change, uncleanness, population explosion and the high per capita cost for new hydric infrastructures are few features which auxiliary bound the provision of water. As a usual matter, supply and/or treatment systems are rare or insufficient in way that the individuals still commonly obtain their required water directly from the nearby streams, or some other ground water source or through rain catching in some parts of world. Many such practices have no surety of obtained clean water quality, which is directly affecting human health. This is so because water can become a source of disease transmission and spread. As per WHO, the foremost parameters affecting water quality in terms of fit for utility proposes regarding the human health, microbial (the presence of coliform enterobacteriaceae like Escherichia coli or thermo-tolerant coliforms), and heavy metal contaminants including arsenic and fluoride. The basis of river ecosystem health management is based on evaluating the water quality of rivers according to physical, physio-chemical, and biological factors. Recently, the assessment of evaluate underground and surface water quality can be done suing various water quality assessment approaches [1]. One such method uses the approach of integrating many water quality factors into a dimensionless value, expressed as water quality index (WQI) which can be regarded as the overall water quality. Latest studies disclose that approximately 65% of groundwater around globe is used for drinking purposes; around 20% for agriculture and 15% is used for industrial needs [1]. It is reported that about a quarter of the world population utilizes groundwater for drinking, particularly developing countries like China and India. It is important to monitor the groundwater quantity and quality. In a race for the advancement, the industrialization of the global world has led to the exploitation of nature and many contaminants are mixing with fresh water sources. Industrial waste containing heavy metals, pharmaceuticals waste and many personal care products, agriculture related pesticides, and micro-pollutants (e.g., endocrine disrupting compounds and nitrosamines) are such contaminants. Long lasting problem in form of serious health problems are also due to pollution of water because of heavy metals. On the other hand, few heavy metals like Zn, Cu, and Co are nutrients for the living organisms. The extreme existence of such heavy metal contamination in potable water poses toxic effects for humans and aquatic ecosystem. In last two decades, wastewater treatment technologies are employed on efficient recycling and treatment of heavy metals and low-concentration pollutants from normal water, wastewater, and already biologically treated wastewater effluents. Such methods are now opted apart from the conventional biological, physical and chemical treatment methods, such as the newly solicitations such as membrane bioreactors, advanced oxidation, reverse osmosis, etc. But, these techniques are frequently considered incompetent due to the huge requirement of feeding of many chemicals and/or energy, high capital/operational costs, and high requirement of supportive infrastructure and engineering and biochemical expertise which prevent their practices in many parts of the world. The existence of iron (Fe) and manganese (Mn) in ground waters is a communal anxiety. The exceeding limits of Fe and Mn in water supplies have affected the health of consumers. The consumption of high concentrations of Fe and Mn can lead to minor indications such as anorexia and weight issues, weakness and lassitude, apathy and learning and/or understanding problems especially in children. And it may also lead to severe diseases such as Parkinson's or Alzheimer's disease. Thus, refinement of groundwater having such metals is very important in social and environmental safety.

In Pakistan, Indus is the main river, coming from Karakorum ranges to south and ultimately goes to Arabian Sea. Blessed by nature, Pakistan has enough resources of surface and ground waters. Figure 1 represents water status of Pakistan i.e. water supply in provinces and per capita water availability decreasing trend [2]. Declining trend is alarming. The large stress on water resources has been put by rapid population growth, urbanization and industrialization. As already stated above while reviewing international scenarios, water plays an important significance in life progressions including evolution and advance industrialization. It is important for every field of our life. However, because of technological developments, potable water is subjected to many impurities of different nature like physical, bio- chemical. Among these, microbiological organisms related pollutants are among the most hazardous impurities which can lead to human health problems or even lead to death in extreme cases. Underprivileged treatment services are reasons for spread of severe faeco-oral water related diseases. In Pakistan, water quality is deteriorated due to intermixing because of leakages as parallel lines are rub for the drinking water, sanitation system and drainage lines. In many cities, the ground water supply is elementary source. Every year a large group of population is affected by these diarrheal related pathogens including viruses, bacteria and some protozoa, which can increase the mortality rate due to diarrhea and its complications. According to one estimate around 2.5 million deaths occur every year due to these diarrheal pathogens. Chlorination is the common technique for disinfection of potable water at treatment plants. It is a technique to have potable water safe and to minimize epidemic diseases. As it is well known that free from color, turbidity, odor, and microbes are the characteristics of the potable water. It should be visually pleasing. As per Pakistan National Conservation Strategy, drought, a reduced amount of rain, and non-development of different water assets decrease water obtainability and rise water scarceness. Inappropriate and deprived water supply for drinking purpose has a excessive health risk to the common people. The water quality is deteriorated due to mixing of toxic chemicals from urban communities and industries in water bodies. It may lead to bad effects to public. Due to prevailing situations, WASA (water and sanitation agency) is mainly concentrating on water quantity due to increased needs instead of water quality. The main reason behind this seems to be the lack of consciousness, competent personnel, quality checking, treatment technology and equipment. Due to presence of micro-pathogens like bacteria, numerous mineral deposits, and carbon-based substances in unsafe potable water, human health is adversely affected. A noteworthy percentage of inhabitants in developing countries are suffering from health-related issues due to unsafe potable water and microbial contamination. The deprived water supply was triggered by the deficiency of water availability. The key causes of water related illneses in potable water are the mixing of industrial wastewater and metropolitan sewage at many locations of the water dispersal system as well as deficiency of water decontamination and water quality checking at treatment plants in Pakistan. Waterborne diseases are ameobiasis, giardiasis, cholera, typhoid and diarrhea/dysentery, intestinal protozoans, gastroenteritis and poliomylitis infections. Such diseases have acquired a huge burden on the statistical mapping of the morbidity and mortality graph in world, about 80% of all the diseases are related with diseases due to sanitation problem and are responsible for 33% of mortality. In this work, different perspectives about water quality of filtration plant are reviewed for use by the common people. Different sources of water supply are briefed. The discussions about water quality importance, processes involved in filtration, different tests on assessment of water quality and guidelines for safe water supply are made. The key goal of this study is to highlight the areas where improvement can be suggested and investigated in future. For this to happen effectively, this literature research is made collaboratively from perspectives of engineering (water supply) and medical (microbiology).

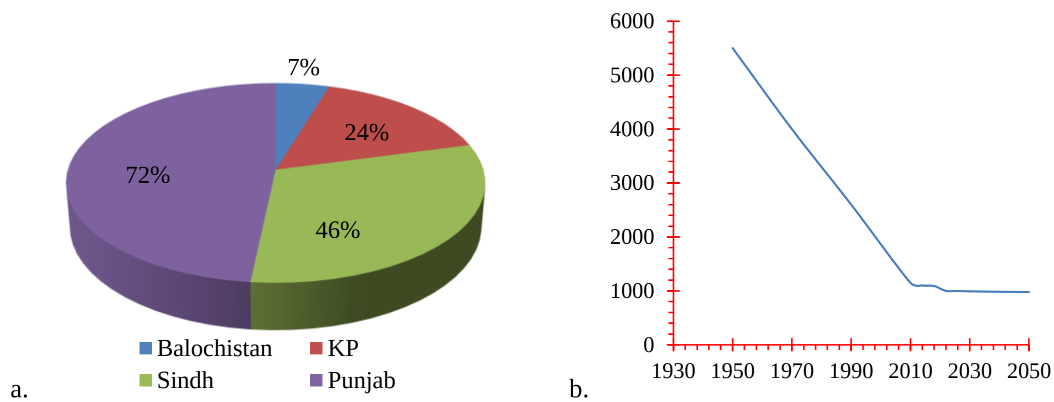


Figure 1: Water status in Pakistan by Daud et al. [2], a) Water supply in provinces, and b) per capita water availability (Note: graphs are reproduced for better quality)

2 RESEARCH SIGNIFICANCE AND IMPORTANCE OF WATER QUALITY FOR HUMAN HEALTH

The quality of drinking water has a great influence over the health of community. The mixing of sewage and water supply creates a lot of problems. Faecal material can make water contaminated due to insufficient safety of the reservoirs, insalubrious use by the community at that point, and inadequate domestic administration practices. Fecal contamination is a CrAssphage, bacteriophages are normally present in human feces and their detection can be done for the assessment of swage contamination in the water. This was done by Ahmed et al. [3] with the help of PCR and gene detection. The sewage tracking mechanism can help in tracking and removing the source. In another study by Gizachew et al. [4], the amount of microbiological contagion of potable water resource from safe water location to houses and its usage among recipient family unit of Boloso Sore woreda, Wolaita zone, Ethiopia was assessed. The bacteriological analysis of water in a cross-sectional survey was made. There were 545, 75 and 18 samples of households for water handling practices, stored water from homes and water for faecal coliform test, respectively. Faecal coliform was positive for 60% superficial wells, 60% of dwindling hand-dug boreholes, and 25% of secure on-spot springs. In addition, it was positive for 44% of water source samples and 91% of household water samples. Unsafe water usage was found in 38% households. World Health Organization water quality guideline was non-compliance. Adeyemi et al. [5] has reported that one of the primary reasons of deaths and diseases around globe is water contamination. It is accounting for the mortality of around >14,000 individuals each day, preponderance being under the age of 5 years. Thus, frequent monitoring of municipal water supplies is very important. Using standard microbiological approaches, bacteriological content was determined for relative micro-bacteriological analyses of 25 stored borehole water samples at different hostels in Oyo State. The micro-organisms contents and existence of enteric-coliforms pathogenic organism upraised serious alarms as WHO allowable perimeters for over-all coliforms and viable count are 0 MPN/100 mL and 100 cfu/mL, respectively. The organisms secluded are of public health importance as consumption of water contaminated by these organisms might result in gastroenteritis, especially *Escherichia* which is probable fecal contamination. Wu et al. [6] declared groundwater vital to ensure water supply in the Ordos basin, China. A total of 35 groundwater samples were analyzed for seventeen physicochemical factors. The model recommended by the United States Environmental Protection Agency (USEPA) was used to quantify the health risk. Also, to assess the overall groundwater quality, water quality index (WQI) is used with human health risk weighting. Adults were at lower risk than children. For both adults and children, many groundwater samples were at undesirable health risks. Many samples were not good for drinking because 11.43 % and 17.14 % of all tested samples were poor quality water and very poor quality water, respectively.

Micro-pollutants (or emerging contaminants) are comprised of a widespread collection of natural and synthetic substances, e.g., personal care products, pharmaceuticals, agrochemicals, and steroid hormones (Quesada et al. [7]). Many such compounds are released into the environment uninterruptedly via domestic sewage treatment systems. There are low-cost adsorbents which can remove main pharmaceuticals traces in runoff water, concentrating on municipal and agro-industrial wastes as precursors. In the arid environments of Patagonia (Argentina), water is a scarce resource for human consumption (Morales et al. [8]). Considering local perspectives and scientific contributions, water quality was assessed through an ethnolimnological, interdisciplinary methodology. Variances were perceived between scientific and local viewpoints in terms of water quality (microbiological and chemical). Many water sources utilized by population showed water of deficient quality for human use (61%).One the other hand, users considered the water to be fresh, transparent, and delicious. Generally, users do not identify the worsening of their water supply. Daud et al. [2] reported that potable water quality is getting deteriorated on daily basis in Pakistan due to shocking increase in rapid industrialization and population. Around 20% of the Pakistan's whole population is having safe potable water. The rest 80% of population is enforced to use unsafe potable water due its scarcity. The main basis of uncleanness is sewage (fecal) which is broadly mixed into potable water supplies network. Inferior basis of micro-pollution is the dumping of fertilizers from agriculture sources, insecticides, and toxic chemicals from industrial effluents into the water storage bodies. There is instantaneous necessity to take protecting actions using management tools to incredulous unhygienic circumstance of potable water supplies in Pakistan.

3 MECHANISMS INVOVLVED IN FILTRATION PLANTS

A big issue is membrane fouling in the ultrafiltration (UF) for removing natural organic matter (NOM) from water (Yang et al. [9]). Different aspects like transition fouling the initial intermediate pore blocking, and the final stage of limited cake growth can predict the leading membrane fouling patterns. A substantial decrease of cake filtration coefficients and a small reduction in pore blocking coefficients were detected with extended UV/TiO2 pretreatment time. One the other hand, photocatalytic pretreatment showed a small effect on the mitigation of irretrievable fouling that was largely dominated by HPI fractions.

3.1 Water supply to filtration plant

In Malaysia, almost every house is presently having outdoor water filtration (OWF) system as part of home appliance (Kamil et al. [10]). The quality of water supply needs to be improved using filtration plant. The aim was to understand qualitatively the prerequisite of OWF system through consciousness of the users. Also, the performance of the system was determined by measuring residual chlorine for sample of seven houses. The efficiency was in the range of 76% to 96% and the users were rarely aware of filter media types and water factors related to effluent water quality. National standards for drinking quality water [2] are provided in Figure 2. This shows the standard values for Pakistan and also comparison is shown with WHO standards.

Parameters	Standard values for Pakistan	WHO standards
	Biological	
All water intended for drinking (*E. coli* or thermotolerant coliform bacteria)	Must not be detectable in any 100 mL sample	Must not be detectable in any 100 mL sample
Treated water entering the distribution system (*E. coli* or thermotolerant coliform and total coliform bacteria)	Must not be detectable in any 100 mL sample	Must not be detectable in any 100 mL sample
Treated water in the distribution system (*E. coli* or thermotolerant coliform and total coliform bacteria)	Must not be detectable in any 100 mL sample In case of large supplies, where sufficient samples are examined, it must not be present in 95% of the samples taken throughout any 12-month period	Must not be detectable in any 100 mL sample In case of large supplies, where sufficient samples are examined, it must not be present in 95% of the samples taken throughout any 12-month period
	Physical	
Color	≤15 TCU	≤15 TCU
Taste	None	None
Odor	None	None
Turbidity	<5 NTU	<5 NTU
Total hardness as $CaCO_3$	<500 mg/L	—
TDS	<1000	<1000
pH	6.5–8.5	6.5–8.5
	Chemical	
Essential inorganic	mg/L	mg/L
Aluminum (Al) mg/L	≤0.2	0.2
Antimony (Sb)	≤0.005 (P)	0.02
Arsenic (As)	≤0.05 (P)	0.01
Barium (Ba)	0.7	0.7
Boron (B)	0.3	0.3
Cadmium (Cd)	0.01	0.003
Chloride (Cl)	<250	250
Chromium (Cr)	≤0.05	0.05
Copper (Cu)	2	2
Toxic inorganic	mg/L	mg/L
Cyanide (CN)	≤0.05	0.07
Fluoride (F)*	≤1.5	1.5
Lead (Pb)	≤0.05	0.01
Manganese (Mn)	≤0.5	0.5
Mercury (Hg)	≤0.001	0.001
Nickel (Ni)	≤0.02	0.02
Nitrate (NO_3)*	≤50	50
Nitrite (NO_2)*	≤3 (P)	3
Selenium (Se)	0.01 (P)	0.01
Residual chlorine	0.2–0.5 at consumer end, 0.5–1.5 at source	—
Zinc (Zn)	5.0	3
	Organic	
Phenolic compounds (phenols) mg/L		≤0.002
Polyaromatic hydrocarbons (PAH) g/L		0.01 (by GC/MS method)

* indicates priority health related inorganic constituents which need regular monitoring.

Figure 2: National standards for drinking quality water by Daud et al. [2]

3.2 Filtration processes and their efficiency

A technique for large-scale treatment of water in rural areas is proposed to remove arsenic by Kim et al. [11]. This should be easily customized, not rely on electrical power and low-cost. The proposal was a three-dimensional (3D), printed water-filtration system to remove arsenic. In adsorptive filtration, a filter with a smaller internal surface area was less effective than one with a larger surface area. At low temperatures (Average 0.5 °C), the impact of chemical pretreatment and filter design to remove *Cryptosporidium* surrogates present in filter influent water was determined using pilot-scale direct filtration challenge experiments (Liu et al. [12]). The optimization of filter configuration and chemical pretreatment to remove *Cryptosporidium* oocysts surrogates in cold-water conditions in granular media water filtration procedures was emphasized. The desirable procedure is deep bed with optimized chemical pretreatment condition for removing Cryptosporidium surrogates in potable water and can be well-thought-out in full-scale application.

4 DIFFERENT PERSPECTIVES IN WATER QUALITY TESTS

Wu et al. [13] is of the opinion that, to improve water resources management strategies, river water quality evaluation is one of the utmost significant features. Water quality index (WQI) is regarded as one of the utmost regularly used assessment tools. It can be calculated using 17 water quality factors, namely pH, temperature, dissolved oxygen (DO), conductivity, biochemical oxygen demand (BOD5), chemical oxygen demand (COD), total phosphorus (TP),ammonia nitrogen (NH3-N), volatile phenol (VP), oil, sulfide, fluoride, lead (Pb), surfactant, zinc (Zn), arsenic (As) and copper (Cu). It came out to be 88.15, 71.70, 78.92, and 90.12 in winter, spring, summer, and autumn, respectively, for Beiyun River. This indicated the water quality as "good". Passman and Peter [14] used water-miscible metalworking fluids (MWFs) to remove metal. Microorganisms in the environment are vastly varied and fungi and bacteria are recovered from these waters at population densities of > 106 CFU mL-1.

Yazdanbaksh et al. [15] assessed the coastal water quality index (CWQI) and microbiological quality in the Persian Gulf (Bandar Abbas city). Five water samples were taken from different coastal locations in summer and spring seasons. To evaluate the quality of microbiology: Fecal Coliforms, Total Coliforms, Clostridium perfringens and Fecal Streptococci were determined. In addition, CWQI was calculated using 08 physicochemical factors (BOD, DO, Turbidity, TSS, pH, Temperature, Phosphate, Nitrate). It was found that the limits of microbiological indicators were exceeded the guideline and national standard values. Also, weak quality of water was reported with the computed CWQI. Adimalla et al. [1] conducted tests on 105 groundwater samples. These included electrical conductivity (EC), pH, total hardness (TH), total dissolved solids (TDS), magnesium (Mg2+), calcium (Ca2+), potassium (K+), sodium (Na+), sulphate (SO42−), chloride (Cl−), fluoride (F−) and nitrate (NO3−). As per water quality index (WQI), 36% and 60% of groundwater samples were in good and excellent categories, respectively, for drinking purpose. It is advised that groundwater for drinking purposes with high nitrate and fluoride concentration should be avoided.

Ali et al. [16] designed a bench scale study for removal of regeneration and zinc (Zn2+) efficiencies of functionalized-MWCNT (f-MWCNT) membranes. The f-MWCNTs had been merged into polyvinylchloride (PVC) hollow fiber membranes (HFMs), which represented as a substrate and a barrier for MWCNTs leaching to water. The results revealed that, for the synthetic water, over 98%of Zn2+ was removed through f-CNT membranes. Piazza et al. [17] exposed the microbial communities of two natural water management plants from Argentina to elongated term presence of Mn(II). Numerous choosy media had been utilized to culture Mn-oxidizing bacteria (MOB) and a huge number of known MOB and numerous isolates that were not testified before as MOB had been cultivated. These bacteria were categorized to choose that with the maximum Mn(II) oxidation and biofilm formation capacities. The isolation of numerous bacterial strains was to mature an inoculum applicable to progress Mn(II) removal efficiency of sand filter water treatment plants.

5 GUIDELINES FOR POLICY MAKERS

Induced bank filtration, an economical and trustworthy drinking water fabrication technique, customarily has an emphasis on practices affecting the drinking water quality [18]. The current filtration mechanisms are not effective enough to remove small sized microbes that can cause antibiotic resistant diseases so there is need of broad-scale surveillance and monitoring of the proliferation of bacteria containing antibiotic resistance genes in drinking water [19]. Water supply and treatment is considered an issue progressively valued under financial and environmental sustainability focus in any water sector. There is a need for proper utilization of available resources for the water quality improvement [20]. From managerial point of view, an effort should be made to educate, monitoring and awareness of the people, drinking water distribution lines up gradation and protection of sources from contamination, and their proper maintenance. Since legislation of potable water supplies has a poor framework, potable water quality standards should be tentatively made for the treatment/ maintenance of potable water distribution system. The similar approach is also recommended by Daud [2]. To guard water resources and control pollution from its source, WASA (Water and Sanitation Agency) along with the assistance of public and private establishments may take action. An excessive care is likewise essential to prevent the saltwater/hard water mixing with the fresh clean natural ground water assets. To minimize the waterborne diseases spread, an effort should be made for appropriate operative, scrutiny, and specimen analysis (three times in a year) to guarantee harmless potable water as per value standards. To kill pathogens, appropriate repairs of water dissemination system and chlorination is required as per law and regulations. Many studies [15, 16] suggested this procedure. Community consciousness campaigns at all levels (school, college, university, and offices) are good for awareness of safe potable water. Boiled potable water decreases danger of waterborne diseases. Economic and social circumstances of the families also have a key role in reducing diarrheal disease. Maternal education on the living style can also be associated to the potable water quality and to progress their health status. This aspect should also be focused.

6 Conclusion

Following conclusions can be drawn from the conducted literature research:

- Established fact cannot be denied about drinking water quality. Its access can reduce waterborne diseases.
- Economical and easy to maintain filtration plants in sectors of societies can help significantly. Public awareness is also important.
- Government and private institutions should work together for efficient output.
- Scientific knowledge is sufficiently available to assist regularity bodies and public; a proper coordination is must.

These facts enforce to think for a national level plan for any developing country to ensure healthy life for its population. The implementation should be made at local level so that common people can benefit from it.

Acknowledgment

The authors would like to thank every person/department who helped thorough out the research work. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

References

[1] N. Adimalla, L. Peiyue, and V. Sudarshan. "Hydrogeochemical evaluation of groundwater quality for drinking and irrigation purposes and integrated interpretation with water quality index studies." *Environmental Processes,* vol. 5, no. 2, pp. 363-383, 2018.

[2] K. M. Daud, N. Muhammad, A. Shafaqat, R. Muhammad, B. A. Raees Ahmad, S. B. Muhammad, A. U. Muhammad et al. "Drinking water quality status and contamination in Pakistan." *BioMed Research International,* Article ID 7908183, 2017.

[3] W. Ahmed, P. Sudhi, C. Michele, B. Colin, and P. Kaye. "Novel crAssphage marker genes ascertain sewage pollution in a recreational lake receiving urban stormwater runoff." *Water Research,* vol. 145, pp: 769-778, 2018.

[4] M. Gizachew, A. Amha, W. Chala, and A. Etagegnehu. "Bacteriological Contamination of Drinking Water Supply from Protected Water Sources to Point of Use and Water Handling Practices among Beneficiary Households of Boloso Sore Woreda, Wolaita Zone, Ethiopia." *International Journal of Microbiology,* Article ID 5340202, 2020.

[5] O.A. Adeyemi, T.K. Efunwole, and A.A. Olanbiwoninu. "Comparative bacteriological analysis of stored borehole water sources in Oyo town, Oyo State, Nigeria." *African Journal of Microbiology Research* , vol 14, no. 1, pp. 32-41, 2020.

[6] J Wu, Y Zhang, H Zhou "Groundwater chemistry and groundwater quality index incorporating health risk weighting in Dingbian County, Ordos basin of northwest China." *Geochemistry,* pp. 125607, 2020.

[7] H.B. Quesada, A.T. Baptista, L.F. Cusioli, D. Seibert, C. de Oliveira Bezerra, and R. Bergamasco. "Surface water pollution by pharmaceuticals and an alternative of removal by low-cost adsorbents: A review." *Chemosphere,* vol 222, pp. 766-780, 2019.

[8] D. Morales, M. Soledad, L. Epele, A. Ladio, M. Pedro, and G. Alday. "An interdisciplinary approach to perception of water quality for human consumption in a Mapuche community of arid Patagonia, Argentina." *Science of The Total Environment,* vol. 720, pp. 137508, 2020.

[9] T. Yang, X. Houfeng, L. Fen, Y. Qiyong, X. Bingjie, and Z. Changchao. "Effect of UV/TiO2 pretreatment on fouling alleviation and mechanisms of fouling development in a cross-flow filtration process using a ceramic UF membrane." *Chemical Engineering Journal,* vol. 358, pp. 1583-1593, 2019.

[10] N.M. Kamil, F.N. Abdullah, and M. Mizad. Requirement of Outdoor Water Filtration System. *In IOP Conference Series: Earth and Environmental Science,* vol. 498, no. 1, p. 012069. 2020.

[11] K.Kim, M.C.Ratri, G.Choe, M.Nam, D.Cho, and K.Shin. Three-dimensional, printed water-filtration system for economical, on-site arsenic removal. *PLOs one,* vol. 15, no. 4, p.e0231475, 2020.

[12] L. Liu, Y. Wang, S. Craik, W. James, Z. Shu, R. Narain, and Y. Liu. Removal of Cryptosporidium surrogates in drinking water direct filtration. *Colloids and Surfaces B: Biointerfaces,* vol. 181, pp. 499-505, 2019.

[13] H. Wu, Y. Wenjie, Y. Ruihua, Z. Yue, Z. Yunqiang, Z. Yuhang, Y. Qianhui, and L.Aijun, "Evaluating surface water quality using water quality index in Beiyun River, China." *Environmental Science and Pollution Research*, pp. 1-10, 2020.

[14] J.F. Passman, and K. Peter. "Microbiology in Water-Miscible Metalworking Fluids." *Tribology Transactions*, pp. 1-47, 2020.

[15] A. Yazdanbakhsh, R. Mohammad, and A. Masumeh. "Evaluation of Microbiological Water Quality and Coastal Waters Quality Index of Persian Gulf in Bandar Abbas Coastal City, Iran." *Iranian Journal of Health, Safety and Environment*, vol. 6, no. 4, pp. 1344-1347, 2020.

[16[S. Ali, R. U. A. Syed, S. A. Izaz, F. U. Muhammad, A. K. Alicia, and H. Haiou. "Efficient removal of zinc from water and wastewater effluents by hydroxylated and carboxylated carbon nanotube membranes: Behaviors and mechanisms of dynamic filtration." *Journal of Hazardous Materials,* vol. 365, pp. 64-73, 2019.

[17] A. Piazza, C. C. Lucila, P. A. Virginia, S. Graciela, O. Jorgelina, and G. Natalia. "Environmental bacteria involved in manganese (II) oxidation and removal from groundwater." *Frontiers in Microbiology,* vol. 10, pp. 119, 2019.

[18] M. Gillefalk, G. Massmann, G. Nützmann, and S. Hilt. "Potential impacts of induced bank filtration on surface water quality: A conceptual framework for future research." *Water*, vol. 10, no. 9, 1240, 2018.

[19] L. Ma, L. Bing, and Z. Tong. "New insights into antibiotic resistome in drinking water and management perspectives: a metagenomic based study of small-sized microbes." *Water Research*, vol. 152, pp. 191-201, 2019.

[20] H. M. Ramos, A. McNabola, P.A. López-Jiménez, and M. Pérez-Sánchez. "Smart water management towards future water sustainable networks." *Water*, vol. 12, no. 1, 58, 2020.

2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

SPREADING OF COVID'19 THROUGH WASTEWATER IN UNDERPRIVILEGED SOCIETIES - AN OVERVIEW

[a] Aruba Waqar, [b] Mehak Ali
a: Institute of Environmental Sciences and Engineering, National University of Science and Technology, Islamabad, Pakistan, aruba.ccrd@gmail.com
b: Department of Microbiology, Watim Medical College, Rawat, Pakistan, drmehakali15@gmail.com

Abstract- The prospective spread of unique human coronavirus by means of contaminated food and water and by aerosols-borne itineraries are turning up to be a major up challenge for all. All over the globe, every country is, at the moment, trying to overcome defies imposed by this disease. There is a need to comprehend the destiny of the virus in the environment. In this literature research, different modes of disease transmission with special focus on the wastewater management are emphasized. The literature up till now indicates that, in addition to direct person to person transmission (which is the most common form of transmission), the virus can also be transmitted through air born droplets, and also through feco-oral rout through contaminated food and water. As there is a knowledge gap indicating no evidence about transmission of coronavirus through the untreated potable water, questions regarding the consequences of non-availability or poor wastewater management strategies, increasing population rate, and failing economy of many countries, need to be addressed. It is concluded that more research is needed to estimate the future of coronavirus and form strategies for its eradication.

Keywords- Waste water, Sewage associated, SARS-CoV-2, Virus-containing aerosols, ARDS, water management.

1 INTRODUCTION

The current epidemic circumstances of coronavirus have a constant state of panic and fear for every country of the world and it is promptly changing with worldwide distribution [1]. SARS-CoV-2 (Severe acute respiratory syndrome coronavirus 2) also known as COVID-19 (coronavirus disease of 2019) is a member of the Coronaviridae family of viruses that can cause humble form of mild flu or can lead to life threatening situation like severe acute respiratory disease that can lead to death]2-4]. The very first case of SARS-CoV-2 was reported in 2019 hence was named as coronavirus disease-2019 or COVID-19 [5]. This virus has shown to be highly contagious, and can spread directly from person to person by direct contact and by respiratory droplets/ aerosols, thus leading to a pandemic that has involved the whole globe rather too quickly [6]. Recently the virus has shown evidence of transmission by oral route through contaminated water supply apart from being transmitted through the inhalational route [7, 8]. The understanding of the spread of the virus took a turn when the ribonucleic acid (RNA) of the virus was identified in the coronavirus infected patient's stool, suggesting the spread by fecal-oral route [9-11]. With this revelation, the prospect of gastrointestinal infection by coronavirus is deliberated by studying the angiotensin-converting enzyme 2 receptor, on which the virus acts, and viral nucleocapsid and GIT (gastrointestinal tract) tissue by staining of gastrointestinal tissues. It is suggested that the transmission of the virus via feco-oral route is much greater because the viral RNA had been found in samples taken from almost every part of the GITract [13, 14]. Even though coronavirus has not regarded as an airborne virus, but the virus utilizes air for its transportation by its adsorption of dust or particulate matter (PM) principally if these particles cart humidity. This is also liked with the phenomenon of virus-laden-aerosols conduction. It is recently studied in Italy that if air pollution of any city exceeds the set limit from that of PM10, there is higher infection rate of COVID-19 in that city [15]. It is proposed that the infection rate is directly related with the amount and the number of days of air pollution and the wind dynamics in a particular city or area. The areas with high pollution have a greater infection rate. A study conducted in Lombardy and Emilia Romagna, Italy where the virus showed maximum lethality as compared with rest of world, making the conclusion that the quality of air in the city is correlated with the higher infectivity of SARS-CoV-2 [16]. Another study conducted in

New York City concluded that the face coverage is highly beneficent because of high virulence of the virus transmission through the air born route [17].

In neglected societies, the environmental condition favors the persistence of SARS-CoV-2 and also its lethality, making it a huge challenge for the community. This is because of the fact that poor sanitary and health care facilities making the spread of the virus in less time [18]. This places a lot of pressure on the WWTPs (waste water treatment plants) for the treatment of the wastewater having virus-contamination. Many neglected societies do not have well equipped systems for wastewater treatment that can remove viruses. These have not been prepared with the essential equipment to eliminate viruses efficiently. For instance, in developing countries like Pakistan, there is no wastewater treatment plant (WWTP) that is functioning in the entire region of different cities; rather e.g. there are some stabilization pools in Faisalabad to treat wastewater of the city. Likewise, in many areas of Nigeria, such as Benue, Kogi, Kwara, Niger, and Plateau, there are non-functional wastewater treatment conveniences whereas in other states like Akwalbom, Abia, Anambra, Imo, Ondo and Bayelsa, there is no facility for wastewater [19-21]. Currently in many parts of world, the wastewater has been discharged unswervingly in native streams and rivers with no or partial treatment [22, 23]. In this work, different pathways taken by the virus are briefly discussed along with wastewater managements and its perspectives are reviewed for the betterment of common people. The fundamental goal of this study is to highlight the strategies for the disease control and to suggest the points which need focus in the where improvement can be suggested and investigated in future. For this to take place commendably, this collected literature research is conducted by the collaboration from perspectives of engineering (wastewater) and medical (microbiology) point of view. Figure 1 demonstrates different transmission paths of coronavirus from improper waste management and aerosols formation.

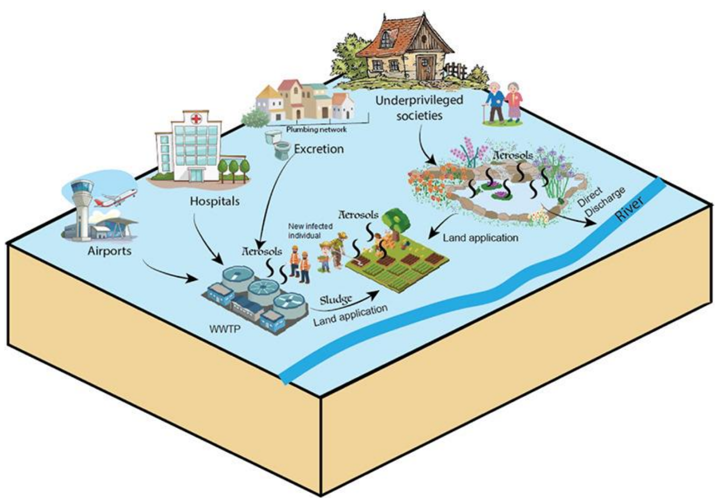


Figure 1: Different route of transmission of SARS-CoV-2 virus from improper waste management and formation of aerosols [24].

2 GIT TRANSMISSION

The GIT involvement of the virus was emphasized by finding the traces of viral RNA in almost every tissue of the gut lining [13, 14].The GIT route orthodoxly trails 5-Fs pathways like fingers, fomite, fluids, flies, and field (Figure 2). Up till now regarding COVID-19, there is very limited know-how on spread of disease via fluids and fields. On the other hand, the involvement of fomites (e.g., surfaces and clothes), flies, and fingers (direct contact) has been debated [1, 25]. It is proposed that SARS-CoV-2 has characteristic similarity with that of SARS-CoV-1 on the basis of morphology and structure and genetics [26]. On this basis like other coronaviruses its transmission could be liked with that of feco-oral route. In Hong Kong during the eruption of the coronavirus in 2003, insufficient drainage systems were acknowledged as the chief source of fecal-oral transmission [1, 27]. After entering the sewerage, the virus forms aerosols spread when it is mixed with fecal particles [28]. These droplets/aerosols initiating from virus-rich excreta were out broke with strong upward air flows, non-functional derisory traps, and water seals. The airborne spread path was further supported with the extract ventilation system of bathroom. This eventually drew air within the area of apartment, therefore facilitating extended-range human-to-human spread through movement of air. As a whole, within one 50 storied apartment building, many confirmed individuals (342) and 42 demises had been reported. Later on, the findings were verified by studying the cross-contamination mechanisms. In past, other viruses had also been spread by fecal–oral path like gastroenteritis virus.

Though, no solid evidence occurs for the transmission of COVID'19, such aspects are significant to be considered for understanding the SARS-CoV-2 future.

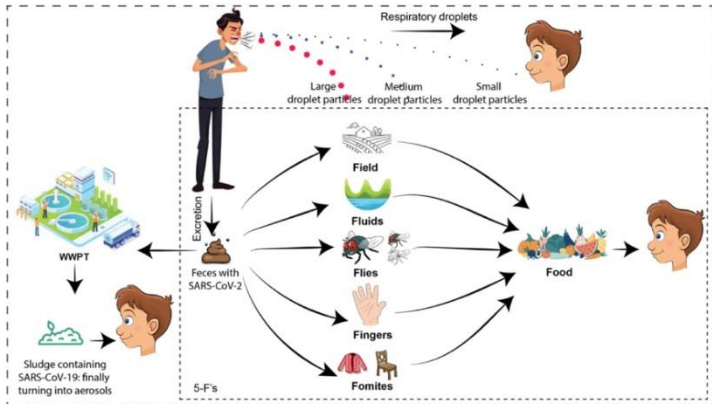


Figure 2: Pathway illustration of coronavirus spread by means of fecal-oral path [24].

3 AEROSOLS/ DROPLET–BORNE TRANSMISSION

The COVID-19 virus is also assumed to be associated with air conditioner [29]. In the early stage of pandemic, in a restaurant of Guangzhou city in China, three families had a get to gather at lunch and later on developed symptoms of coronavirus in a successive way. On day 1, only one individual had symptoms, but later on, 9 more family members got infected. As in a closed space and strong air flow of the air conditioner the droplets are propagated further as the human atomize the virus loaded particles by sneezing, coughing, or even usual breathing via an infected individual. The bigger respirational droplets (of >5 μm size) stay for a short period of time in the air and settle down at around < 1 m distance. On the other hand, small aerosolized droplets (of <5 μm size) can persist for a longer period of time in the air and could go > 1 m distances. The fine aerosols (i.e. PM2.5) might penetrate acutely in respirational tract, ultimately affecting the other important organs of the body [14]. Keeping in focus the transmission of the respiratory droplets there is a requirement for the development of necessary strategies during the construction of new buildings and the installment of the ventilation system in order to minimize the risk of indoor transmission of the disease. The engineering control of the ventilation system should be done as to include maximum ventilation, installment of air filters and purifiers, and avoidance of air recirculation and overcrowding. These measures can easily implemented and are cost effective if the strategies are implemented at appropriate time. It is believed that these engineering control measures of buildings along with the other control measures like wearing face mask, maintain a safe distance, proper hand hygiene, isolation and quarantine could have additional benefits in minimizing the transmission of the disease in public places like hospitals, schools, restaurants and offices. The detection of COVID 19 in the indoor air samples of hospitals raised many questions regarding the viability of the virus and the concentration of the virus and the relation of infectious dose. It has been observed that the virus remains viable in the air and the viability depends upon the condition of the environment like humidity and temperature etc. To assess the viability of virus in the laboratory setting, the stability and characteristics of coronavirus and other air born viruses like the MERS (Middle East respiratory syndrome) coronavirus were compared [30]. MERS-CoV virus had been found in air specimens, taken from hospitals of South Korea. This virus caused 186 infected cases as well as 36 demises, resulting in the closure of hospitals temporarily. For measuring spread of coronavirus by aerosols, SARS-CoV-1 and SARS-CoV-2 were assessed for their stability on lab-generated aerosols. It was recounted that the later one could remain up to 3 h in the aerosols in the humid environment of around 65%. It is advised to further evaluate the behaviour of the virus at different humidity levels. The detection of viable samples of virus prompt the question of safe exposure levels. Even though a decrease in infectious titer had been experienced with the passage of time, i.e. half-lives were comparable for both SARS-CoV-1 and SARS-CoV-2 and TCID50 (fifty-percent tissue culture infective dose) decreased from 103.5 to 102.7/L of air. In recent time, SARS-CoV-2 with285–1130 copies/m^3 was detected in aerosols taken from the environment of hospital [14]. This leads to the opinion that there might be a viral spillage due to the production of respiratory droplets or aerosols produced by the infected patients. In Hong Kong, in the course of the past occurrence of virus outbreak, the SARS-CoV-1 was capable of entering the separate buildings and homes. Another question arises here that what might be the impact of ambient temperature on the SARS-CoV-2 survival in the air. For answering the question, a study was conducted on coronavirus infections in China (122 cities) during period of Jan-Feb 2020 [31]. No decrease was found in infection rate due to hot environment. This finding is in contrast to the observations made about poor existence of SARS-CoV-1 at lower and high temperatures, aiding the wide spread and infections [32].

4 WASTEWATER HAVING SARS-COV-2

The general signs of COVID 19 include fever, cough, diarrhea and difficulty in breathing and the RNA of the virus are found in the feces of asymptomatic as well as the symptomatic patients [14]. According to this scenario the municipal wastewater of the effected community could contain viruses. By default the plumbing system harbors many microorganisms including viruses like coronavirus [33]. In 2003, a report was published by World Health Organization (WHO) after coming across a different scenario when the housing facility in Hong Kong was affected by SARS virus and there were 342 confirmed cases in a 50 story building with 42 deaths due to SARS virus. The transmission cause was recognized as the defected wastewater plumbing system which facilitated the virus louden vapor partials through the fittings in the bathrooms. The interconnected plumbing system can lead to spread and super spread of the disease. This is a matter of concern in the high risk facilities like hospitals and community centers or other healthcare buildings. As the virus is shredded in the stool the presence of virus (RNA, messenger RNA or capsid) could be used for evaluation. The existence of coronaviruses in WWTPs is determined via numerous factors like the occurrence of oxidants and carbon-based matter; variations in pH and temperature; and copiousness of antagonistic bacteria [1, 34]. Firstly, suspended solids and organic matter in wastewater could offer shield to viruses which has adsorption capability to such particles, decreasing the deactivation effectiveness [34]. The persistence of coronaviruses depends upon multiple factors, and in treated sewage and pure water, it lives up to many days [35]. The existence of oxidants can affect the viral envelope integrity (a very fragile structure) [36]. In the past, SARS-CoV-1 virus had been incapacitated in wastewater in the presence of strong oxidants, for example, free chlorine [34]. The WHO recommended dose of free chlorine near chlorination (i.e. at pH < 8.0, ≥ 0.5 mg/L after contact time of at least 30 minutes) may not be adequate enough to treat the current coronavirus having high viral load [37]. In a study, the septic tank having wastewater of a hospital had viral RNA. This had been disinfected with dose of 800 g/m^3 sodium hypochlorite (one and a half contact time and >6.5 mg/L free chlorine). In general, the existence of coronaviruses may be related to the temperature. For instance, SARS-CoV-1 at 20 °C could live up to 48 hours in the dechlorinated tap water, hospital wastewater, and domestic sewage. But, this duration was extended to 2.5 weeks when existing in the urine and 72 hours when present in organic matter (feces). SARS-CoV-1 had been further capable of its existence at lower temperatures (4 °C) up to > 2.5 weeks in urine or feces and 2 weeks in the wastewater [38]. The existence of antagonistic microorganisms can also have an effect as they enhance the degree of inactivation. The phenomenon is studied in detail at waste water treatment plants in which membrane-bioreactors are available. In the presence of these membrane bioreactors, the inactivation of viruses is done through enzymatic breakdown and predation [39]. The degree of deactivation auxiliary enhances in the sludge (i.e. solid state) in comparison to liquid state. This can be due to highly dense predators and enzymes in solid state [40]. Many of these outcomes are verified for enveloped viruses containing Coronaviridae family members. In short, more research on SARS-CoV-2 is necessary to make further related assumptions.

5 IMPENDING THREATS FOR NEGLECTED SOCIETIES

In many parts of the world majority of population do not have adequate facilities like clean water, toiletries and other healthcare facilities. Furthermore due to space constraints and over-crowding in most areas the physical distancing and self-quarantine seems impractical and difficult so have influence in the rapid spread of the disease. In the neglected societies there are no proper waste management facilities and the WWTPs produce a huge quantities of solid-state sludge. As it is well known that the sludge carry's many microorganisms including many bacteria and viruses including SARS-CoV-2 [41, 42]. The early detection of RNA in the fecal matter can have beneficial effect in the detection of the viral content and its vulnerability for the community. The virus load is very high on solid particles in the viral shedding period. The amount of viral RNA load in principal municipal sewage slush may perhaps be up to many times greater as per their corresponding quantities in raw wastewater [9]. The microorganism especially viruses can survive for a long period of time under appropriate circumstances [43]. For instance, after 17 months of dumping, human enteric viruses had been found in the residues taken from Atlantic Ocean (i.e. sewage slush disposed location) [44]. Though, few societies do treatment of their sewage sludge for decreasing the microorganism's existence by dewatering, thickening, composting processes or digesting, it is yet not known if such practices can adequately inactivate/remove the coronavirus. The recent know-how of the adsorption abilities of virus on particles of sludge endorses suitable treatment before discharging/disposing into environment. In addition, deprived communities could not bear expenses to buy the disinfection chemicals which can aid to deactivate the viruses. For example, in regions like Tunisia India, and Egypt, no treatment of wastewater is done beyond secondary phase [20]. The hazard linked with the existence of coronavirus in the runoff water seems insignificant; nonetheless, this condition for underdeveloped countries may be different because of poor waste management practices and improper sanitation. The other apprehension in underdeveloped countries is the cross-transmission of the systems of potable water with inappropriate wastewater management. Though, no recent indication confirms the existence of human SARS-CoV-2 in ground or runoff water [36]. Additionally, the timing and intensity of preventive actions should be made with care in deprived communities as the death rate may increase in these areas because of poor wastewater management, health care, and overpopulation. During spread of Spanish flu in 20th century, around 30% deaths were observed in India only because of the recurrent spreads [45]. In addition, modeled outcomes have concluded that coronavirus has the capability of making a substantial spread irrespective of establishment time. At most, detail wastewaters monitoring in deprived communities should have topmost urgency unless majority of the inhabitants is vaccinated. A big challenge in such communities is to have economical screening systems for easy detection at early age so as to have control situation.

6 CONCLUSION

In this work, different pathways taken by the virus are briefly discussed along with wastewater managements and its perspectives are reviewed for the betterment of common people. The fundamental goal of this study is to highlight the strategies for the disease control and to suggest the points which need focus in the where improvement can be suggested and investigated in future. For this to happen effectively, this literature research is made collaboratively from perspectives of engineering (wastewater) and medical (microbiology). Following conclusions can be drawn from the conducted literature research:

- The SARS-CoV-2 could be transmitted through fecal-oral contamination and also air born-virus-laden aerosols/droplet routes. However, there may be a difference in the outcome in different regions according to the different circumstances such as the level of control measures, the cultural norms, hygienic habits of the people, and the treatment facilities.
- The rate of pollution has a direct relation with the rate of infection of COVID-19, the higher the rate of pollution in a specific area the greater is the infection rate
- The wastewater treatment and recycling depends on the knowledge regarding the treatment options and the available resources, so detail investigation should be made to interpret the virus fortune in different environments.
- Since many underdeveloped regions are deficient of basic infrastructure to eliminate such viruses from whole water cycle, this condition can cause numerous spreads as were seen in the past.

The chain of transmission of SARS-CoV-2 could be broken or slowed down by proper wastewater management and good hygiene practices. Also wearing a facemask could decrease the infection rate. A successful health program depends upon the formation of proper strategies which require accurate knowledge regarding the proper disposal of waste and the reutilization of different products in order to minimize the spread of the disease. To address this issue further research is required based on thorough on-field testing and analyses.

ACKNOWLEDGMENT

The authors would like to thank every person/department who helped thorough out the research work. The careful review and constructive suggestions by the anonymous reviewers are gratefully acknowledged.

REFERENCES

[1] WHO. "Water, Sanitation, Hygiene, and Waste Management for the COVID-19 Virus: Interim Guidance, 23 April 2020". 2020.World Health Organization: https://apps.who.int/iris/handle/10665/331846 (Accessed 25th April 2020).

[2] J. F. Chan, K. H. Kok, Z. Zhu, H. Chu, K. K. To, S. Yuan and K. Y. Yuen. "Genomic characterization of the 2019 novel human-pathogenic coronavirus isolated from a patient with atypical pneumonia after visiting Wuhan". *Emerging Microbes & Infections*, vol. 9, no. 1, pp.221-236, 2020.

[3] A. E. Gorbalenya, S. C. Baker, R. S. Baric, et al., The species severe acute respiratory syndrome-related coronavirus: classifying 2019-nCoV and naming it SARS-CoV-2. *Nat. Microbiol.* 5, 536–544. 2020. https://doi.org/10.1038/s41564-020-0695-z.

[4] C. I. Paules, H. D. Marston, A. S. Fauci. "Coronavirus infections—more than j;8ust the common cold". *Jama* vol. 323, no. 8, pp. 707–708. 2020.

[5] Y. Huang, M. Tu, S. Wang, S. Chen, W. Zhou, D. Chen, L. Zhou, M. Wang, Y. Zhao, W. Zeng. "Clinical characteristics of laboratory confirmed positive cases of SARS-CoV2 infection in Wuhan, China:a retrospective

single centeranalysis". *Travel Medicine and Infectious Disease,* 2020. 101606 https://doi.org/10.1016/j.tmaid.2020.101606 Advance online publication.

[6] M. Cascella, M. Rajnik, A. Cuomo, S. C. Dulebohn, R. Di Napoli. "Features, evaluation and treatment coronavirus (COVID-19)". *Statpearls [Internet]. StatPearls Publishing.* 2020.

[7] J. Hindson. "COVID-19: faecal–oral transmission?" *Nature Reviews Gastroenterology & Hepatology.* vol. 17, pp. 259–259. 2020.

[8] J. Wang, G. Du. "COVID-19 may transmit through aerosol". *Irish Journal of Medical Science,* vol. 1971, pp. 1–2. 2020.

[9] W. Ahmed, N. Angel, J. Edson, K. Bibby, A. Bivins, J. W. O'Brien, P. M. Choi, M. Kitajima, S. L. Simpson, J. Li, B. Tscharke, R. Verhagen, W. J. M. J. Smith, Zaugg, L. Dierens, P. Hugenholtz, K. V. Thomas, J. F. Mueller. "First confirmed detection of SARSCoV-2 in untreated wastewater in Australia: a proof of concept for the wastewater surveillance of COVID-19 in the community". *Science of The Total Environment*, vol. 728, 138764. 2020. https://doi.org/10.1016/j.scitotenv.2020.138764.

[10] R. Grassia, S. Testa, A. Pan, C. B. Conti. "SARS-CoV-2 and gastrointestinal tract: the dark side of the pandemic". *Digestive and Liver Disease* vol. 52, no. 7, pp 700–701, 2020.

[11] Q. Wen, J. Yang, T. Luo. "First case of Covid-19 in the United States". *The New England journal of medicine,* vol. 382, e53. 2020. https://doi.org/10.1056/NEJMc2004794.

[12] F. Xiao, M. Tang, X. Zheng, Y. Liu, X. Li, H. Shan. "Evidence for gastrointestinal infection of SARS-CoV-2". *Gastroenterology,* vol. 158, pp. 1831–1833, 2020.

[13] Y. Wu, C. Guo, L. Tang, Z. Hong, J. Zhou, X. Dong, H. Yin, Q. Xiao, Y. Tang, X. Qu. "Prolonged presence of SARS-CoV-2 viral RNA in faecal samples". *The Lancet Gastroenterology & Hepatology,* vol. 5, no. 5, pp. 434–435. 2020.

[14] H. Zhang, Z. Kang, H. Gong, D. Xu, J. Wang, Z. Li, Z. Li, X. Cui, J. Xiao, J. Zhan, T. Meng, W. Zhou, J. Liu, H. Xu. "Digestive system is a potential route of COVID-19: an analysis of single-cell coexpression pattern of key proteins in viral entry process". *Gut,* vol. 69, no. 6, pp. 1010–1018. 2020.

[15] M. Coccia. "Factors determining the diffusion of COVID-19 and suggested strategy to prevent future accelerated viral infectivity similar to COVID". *Science of the Total Environment,* vol. 729, 138474, 2020.

[16] E. Conticini, B. Frediani, D. Caro. "Can atmospheric pollution be considered a cofactor in extremely high level of SARS-CoV-2 lethality in northern Italy?" *Environment Pollution,* vol. 261, 114465, 2020.

[17] R. Zhang, Y. Li, A. L. Zhang, Y. Wang, M. J. Molina. "Identifying airborne transmission as the dominant route for the spread of COVID-19". *Proceedings of the National Academy of Sciences*, 202009637, 2020. https://doi.org/10.1073/pnas.2009637117.

[18] WHO. "WHO releases guidelines to help countries maintain essential health services during the COVID-19 pandemic". 2020. *https://www.who.int/news-room/detail/3003-2020-who-releases-guidelines-to-help-countries-maintain-essential-health-services-during-the-covid-19-pandemic* (Accessed 10th May 2020).

[19] S. Adesogan. "Sewage technology in Nigeria: a pragmatic approach". *Science Journal of Environmental Engineering Research*, vol. 2013, pp. 1–9. 2013. https://doi.org/10.7237/sjeer/266.

[20] J. R. Adewumi, A. M. Oguntuase. "Planning of wastewater reuse programme in Nigeria". *Consilience,* vol. 15, pp. 1–33. 2016.

[21] D. O. Omole, T. Jim-George, V. E. Akpan. "Economic analysis of wastewater reuse in Covenant University". *Journal of Physics Conference Series (IOP Publishing),* vol. 1299, no. 1, 12125, August. 2019.

[22] M. Afzal, M. Arslan, J. A. Müller, G. Shabir, E. Islam, R. Tahseen, M. Anwar-ul-Haq, A. J. Hashmat, S. Iqbal, Q. M. Khan, "Floating treatment wetlands as a suitable option for large-scale wastewater treatment". *Nature Sustainability*, vol. 2, no. 9, pp. 863–871, 2019.

[23] A. Azizullah, M. N. K. Khattak, P. Richter, D. P. Häder. "Water pollution in Pakistan and its impact on public health—a review". *Environment International,* vol. 37, no. 2, pp. 479–497, 2011.

[24] M. Arslan, B. Xu, and M. G. El-Din. "Transmission of SARS-CoV-2 via fecal-oral and aerosols–borne routes: Environmental dynamics and implications for wastewater management in underprivileged societies". *Science of The Total Environment*, pp.140709. 2020.

[25] Z. D. Guo, Z. Y. Wang, S. F. Zhang, X. Li, L. Li, C. Li, Y. Cui, R. B. Fu, Y. Z. Dong, X. Y. Chi. "Aerosol and surface distribution of severe acute respiratory syndrome coronavirus 2 in hospital wards, Wuhan, China, 2020". *Emerging Infectious Diseases*, vol. 26, no. 7, 2020.

[26] C. Yeo, S. Kaushal, D, Yeo. "Enteric involvement of coronaviruses: is faecal–oral transmission of SARS-CoV-2 possible?" *The Lancet Gastroenterology & Hepatology*, vol. 5, no. 4, pp. 335–337, 2020.

[27] J. Peiris, S. Lai, L. Poon, Y. Guan, L. Yam, W. Lim, J. Nicholls, W. Yee, W. Yan, M. Cheung. "Coronavirus as a possible cause of severe acute respiratory syndrome". *Lancet,* vol. 361, no. 9366, pp. 1319–1325, 2003.

[28] G. Qu, X. Li, L. Hu, G. Jiang. "Animperative needforresearch ontheroleofenvironmental factors in transmission of novel coronavirus (COVID-19)". *Environmental Science & Technology,* vol. 54, no. 7, pp. 3730–3732, 2020.
[29] J. Lu, J. Gu, K. Li, C. Xu, W. Su, Z. Lai, D. Zhou, C. Yu, B. Xu, Z. Yang. "COVID-19 outbreak associated with air conditioning in restaurant, Guangzhou, China". *Emerging Infectious Diseases,* 26 (7). 2020.
[30] N. van Doremalen, T. Bushmaker, D. H. Morris, M. G. Holbrook, A. Gamble, B. N. Williamson, A. Tamin, J. L. Harcourt, N. J. Thornburg, S. I. Gerber. "Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1". *The New England Journal of Medicine,* vol. 382, no. 16, pp. 1564–1567. 2020.
[31] Y. Zhu, J. Xie. "Association between ambient temperature and COVID-19 infectionin 122 cities from China". *Science of Total Environment,* 138201, 2020.
[32] J. Wang, K. Tang, K. Feng, W. Lv. "HighTemperature and High Humidity Reduce the Transmission of COVID-19". *(Available at SSRN 3551767).* 2020.
[33] WHO. "Inadequate plumbing systems likely contributed to SARS transmission. in: Inadequate Plumbing Systems Likely Contributed to SARS Transmission".: https:// www.who.int/mediacentre/news/releases/2003/pr70/en/ (Accessed 29th April, 2020). 2003.
[34] P. M. Gundy, C. P. Gerba, I. L. Pepper. "Survival of coronaviruses in water and wastewater". *Food and Environmental Virology,* vol. 1, no. 1, 10. 2008.
[35] L. Casanova, W. A. Rutala, D. J. Weber, M. D. Sobsey. "Survival of surrogate coronaviruses in water". Water Research, vol. 43, no. 7, pp. 1893–1898. 2009.
[36] G. La Rosa, L. Bonadonna, L. Lucentini, S. Kenmoe, E. Suffredini. "Coronavirus in water environments: occurrence, persistence and concentration methods-a scoping review". *Water Research,* vol. 179, 115899, 2020. https://doi.org/10.1016/j.watres.2020.115899.
[37] D. Zhang, H. Ling, X. Huang, J. Li, W. Li, C. Yi, T. Zhang, Y. Jiang, Y. He, S. Deng, X. Zhang. Potential spreading risks and disinfection challenges of medical wastewater by the presence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV2) viral RNA in septic tanks of Fangcang Hospital. *Science of Total Environment,* vol. 741, 140445. 2020.
[38] X. W. Wang, J. S. Li, M. Jin, B. Zhen, Q. X. Kong, N. Song, W. J. Xiao, J. Yin, W. Wei, G. J. Wang, B. y. Si, B. Z. Guo, C. Liu, G. R. Ou, M. N. Wang, T. Y. Fang, F. H. Chao, J. W. Li. Study on the resistance of severe acute respiratory syndromeassociated coronavirus. *Jounal Virology Methods,* vol. 126, no. 1, pp. 171–177. 2005.
[39] X. D. Hao, Q. L. Wang, J. Y. Zhu, M. C. Van Loosdrecht, Microbiological endogenous processesinbiological wastewatertreatmentsystems. Crit. Rev. *Environment Science &Technology,* vol. 40, no. 3, pp. 239–265, 2010.
[40] R. M. Chaudhry, K. L. Nelson, Jr. E. Drewes. "Mechanisms of pathogenic virus removal in a full-scale membrane bioreactor". *Environment Science &Technology,* vol. 49, no. 5, pp. 2815–2822, 2015.
[41] I. Xagoraraki, Z. Yin, Z. Svambayev. "Fate of viruses in water systems". *Journal of Environmental Engineering,* vol. 140, 04014020, 2014.
[42] K. Xiao, S. Liang, X. Wang, C. Chen, X. Huang. "Current state and challenges of fullscale membrane bioreactor applications: a critical review". *Bioresources and Technology,* vol. 271, pp. 473–481, 2019.
[43] A. Schlindwein, C. Rigotto, C. Simões, C. Barardi. "Detection of enteric viruses in sewage sludge and treated wastewater effluent". *Water Science and Technology,* vol. 61, no. 2, 537–544, 2010.
[44] S. M. Goyal, W. Adams, M. O'Malley, D. Lear. "Human pathogenic viruses at sewage sludge disposal sites in the middle Atlantic region". *Applied Environment Microbiology,* vol. 48, no. 4, pp. 758–763, 1984.
[45] R. J. Barro, J. F. Ursúa, J. Weng. "The coronavirus and the great influenza pandemic: lessons from the "Spanishflu" for the coronavirus's potential effects on mortality and economic activity". *National Bureau of Economic Research*, 26866. 2020.