PERFORMANCE OF CONCRETE CONTAINING STEEL WASTE FIBERS

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Abstract- Concrete's mechanical properties are significantly influenced by the addition of steel waste fibers. This study investigates the impact of varying dosages of steel waste fibers on the performance of concrete cube specimens. Compression strength tests on cubes reveal a 39% increase in maximum strength when 1% steel waste is added, attributed to improved bonding between steel waste and the concrete matrix. However, it was concluded that higher dosages lead to fiber clustering and inadequate bonding, causing non-uniform distribution and localized stress concentrations, resulting in a modest loss in compressive strength. This study provides valuable insights into how different dosages of steel waste affect the mechanical properties of concrete, informing sustainable building practices and waste management strategies.

Keywords- Concrete, Mechanical properties, Steel Waste, Sustainable construction.

1 Introduction

This research explores the mechanical properties of high-strength concrete reinforced with fibers, aiming to mitigate crack formation and enhance overall mechanical performance for practical applications. The introduction of steel fibers significantly improves concrete's ability to withstand tension, leading to the development of steel fiber reinforced concrete (SFRC) [1]. Studies have shown that incorporating steel waste fibers into concrete enhances its mechanical properties, contributing to more durable and structurally robust constructions [2, 3]. Sustainable construction methods have increased interest in utilizing industrial waste materials in concrete. Steel waste fibers have shown promising results in improving concrete's mechanical properties, but further investigation is needed to determine their optimal concentration and impact on different concrete components [4].

During a past study program, it was concluded that the concrete's ductility and stiffness improved with the inclusion of steel scrap [5]. However, the study observed that with the increasing amount of metal scrap, the workability of the concrete decreased. This finding suggests that there is a trade-off between the improvement in strength properties and the ease of working with concrete. Despite the reduction in workability, the results highlight the potential benefits of incorporating steel scrap waste into concrete mixes to enhance its overall mechanical properties [1]. The authors used various percentages of steel scrap ranging from 0% to 1.5% by volume. A total of twelve cubic specimens and twelve-cylinder specimens were prepared and subjected to laboratory testing after 28 days of curing. The test results demonstrated that the addition of scrap steel had a positive impact on the concrete's compressive and split tensile strengths. Notably, the inclusion of 1.5% scrap steel by volume increased the compressive strength by 5.3%, 0.75% by volume led to a substantial increase of 30.7%, and 0.5% by volume resulted in a notable rise of 26.8%. Similarly, the splitting tensile strength of the concrete also showed improvement with the addition of scrap steel. At 0.5% by volume, the splitting tensile strength increased by 11.2%, at 0.75% by volume it rose by 5.8%, and at 1.5% by volume, there was a 2.5% increase in splitting tensile strength. Additionally, as the amount of scrap steel incorporated into the concrete increased, the peak strain and elasticity modulus of the material also noticeably rose. [1].

Aiello et al. conducted a study with the aim of exploring the mechanical behavior of concrete reinforced with recycled steel fibers (RSF) derived from used tire rubber through a mechanical process [6]. The researchers performed pull-out tests to evaluate the bonding characteristics between the concrete and RSF, enabling them to determine the optimal fiber length for reinforcement. Additionally, flexural tests were conducted to investigate the post-cracking behavior of the RSF-reinforced concrete (RSFRC). The study also examined the compressive strength of the concrete for different volume ratios of RSF and included samples reinforced with industrial steel fibers (ISF) for comparison. The findings revealed that the bond between the recycled steel fibers and the concrete was satisfactory [7]. However, despite the uneven geometrical characteristics of the fibers, they did not seem to have a significant impact on the compressive strength of the concrete. Overall, the study demonstrates the potential viability of utilizing recycled steel fibers from used tire rubber as an alternative reinforcement in concrete. While the bonding characteristics were satisfactory and the compressive strength was not significantly affected, the post-cracking behavior may differ from that of concrete reinforced with industrial steel fibers. These findings provide valuable insights into the mechanical performance of RSF-reinforced concrete and open new avenues for sustainable and eco-friendly practices in the construction industry. In this study program experiments were planned to evaluate the enhancement in mechanical properties of concrete and its cracking behavior. This study aims at exploring the mechanical properties of concrete through (a) Preparation of control mix for cubes, (b) Varying the dosages of steel waste fibers in the mix, (c) Performing strength tests on cubes.

Fiber reinforced concrete has various applications in civil infrastructure projects, offering greater durability and reduced maintenance [2, 8, 9]. The study reveals that fibers improve the strength and durability however, achieving uniform distribution of fibers throughout the concrete mix is crucial for its effectiveness[10, 11].This study investigates optimal dosages of steel waste fibers and their impact on concrete. Unlike previous studies, it compares varying fiber concentrations with industrial steel fibers, offering insights into sustainable construction. The findings demonstrate how specific dosages enhance concrete performance, supporting eco-friendly construction practices.

2 Research Methodology

In this study twelve specimens were tested. The specimen nomenclature was decided according to percentage of fibers and is elaborated in Table 1.

Table 1: Nomenclature of cube specimen

Sr.NO.	Specimen ID	Mix Proportion	W/C Ratio	Steel Fibers Percentage (w.r.t binder)
1	CN (1)	1:1:2	0.45	0 %
2	CN (2)	1:1:2	0.45	0 %
3	CN (3)	1:1:2	0.45	0 %
4	C1 (1)	1:1:2	0.45	1%
5	C1 (2)	1:1:2	0.45	1%
6	C1 (3)	1:1:2	0.45	1%
7	C2 (1)	1:1:2	0.45	2%
8	C2 (2)	1:1:2	0.45	2 %
9	C2 (3)	1:1:2	0.45	2 %
10	C3 (1)	1:1:2	0.45	3 %
11	C3 (2)	1:1:2	0.45	3 %
12	C3 (3)	1:1:2	0.45	3 %

2.1 Material and Methods

In this study it was ensured that well graded coarse aggregate was used. The gradation curve of the coarse aggregates is s shown in Figure 1. The sand used in the mix was the Lawrencepur sand. The gradation curve of fine aggregates is shown in Figure 2.

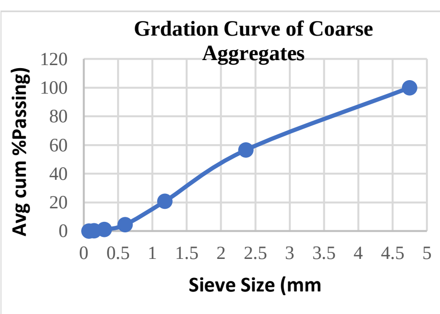

Figure 1: Gradation Curve of coarse aggregate.

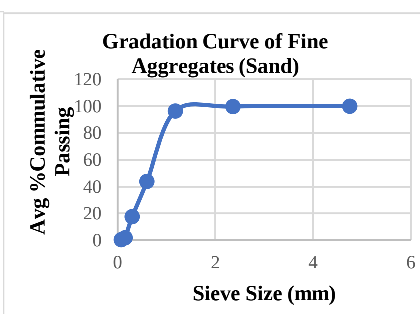

Figure 2: Gradation curve of fine aggregate

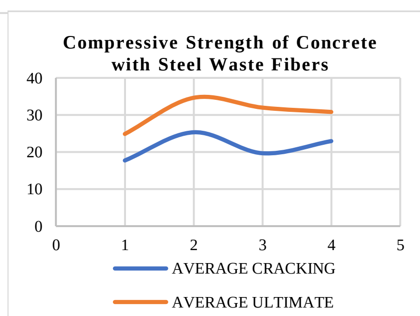

Figure 3: Compressive Strength of Concrete with steel waste fibers

The steel chips (SC) or fibers (SF) Utilized in this study was obtained by the process of recycling old and waste steel found in the local market of Taxila at cheap rates. Results show the gradation curve of steel waste fiber is well graded. The mixer has capacity greater than one cubic yard and set according to ASTM C94/C94 M-21 [12] minimum revolution of 100 and mixing time range 1-5 minutes after putting water, cubes having size of 70 x 70 x 70 mm are used. The twelve cubes were cast having three cubes of normal mix, three containing 1%, three containing 2% and three containing 3% steel waste of binder material respectively. We used the mixed ratio of cement, sand, and coarse aggregate as 1:1:2. The water cement ratio used is 0.45. The water used during the casting process is drinkable water.

2.2 *Procedure of testing*

One of concrete's most important qualities is its compressive strength because it reflects the material's overall effectiveness. On cube specimens of 70 mm x 70 mm x 70 mm, a compressive test was performed in a CTM machine with a 5000 kN capacity. As per ASTM C39, the machine's loading rate is between 20 and 50 psi, or 2.5 and 6.5 kN in our Specimens. The test was carried out on a cube containing three specimens of the control mixture, three specimens of 1% steel waste, three specimens of 2% steel waste, and three specimens of 3% steel waste. The 12 cubes were tested in the on the Compression Testing Machine in the concrete laboratory of UET Taxila. All specimens of control mix and specimens of waste were tested. The first cracking and ultimate cracking load on the cube is noted.

3 Results & Discussion:

Table 2: Compressive strength test results.

CUBE	CRACKING LOAD (kN)	ULTIMATE LOAD (kN)	AREA (mm2)	CRACKING STRENTH (MPa)	ULTIMATE STRENGTH (MPa)	AVERAGE CRACKING	AVERAGE ULTIMATE
CN (1)	125	143	4900	25.51	29.18		
CN (2)	82	112	4900	16.73	22.85		
CN (3)	54	111	4900	11.020	22.65	17.75	24.89
C1 (1)	98	158	4899	20.004	32.25		
C1 (2)	164	164	4900	33.469	33.46		
C1 (3)	111	187	4900	22.653	38.16	25.37	34.62
C2(1)	99	135	4863.5	20.35	27.75		
C2 (2)	83	227	4900	16.93	46.32		
C2 (3)	107	107	4900	21.83	21.83	19.71	31.97
C3 (1)	128	154	4900	26.122	31.42		
C3 (2)	92	144	4900	18.775	29.38		
C3 (3)	118	155	4900	24.081	31.63	22.99	30.81

During the test cracking strength, ultimate strength, average cracking, and average ultimate strength of cube specimens were recorded and is presented in Table 2. The compressive strength of cube having control mix is obtained almost 25 MPa which is the ultimate compressive strength of concrete having mix ratio of 1:1:2 after 28 days. The ultimate compressive strength of cube containing 1% waste is increased by 39% and is increased by 28% by adding 2% steel waste and is increased by 23% by adding 3% steel waste as compared to the control mix. The Cubes show a maximum strength at 1% dosage of steel waste. However, by further adding of steel waste dosage (beyond 1%) the compressive strength is slightly decreased. The maximum compressive strength achieved at 1% dosage which is 39% greater than the control mix. The experimental results of Akhtar Gul [13] also point to the concrete losing compressive strength when steel waste is added in large quantities. One percent waste has a compressive strength that is higher than the control mix, whereas two percent waste has a compressive strength that is slightly lower than one percent waste's and higher than the control mix. The higher dosage of waste reduced the strength of concrete due to the loss in the workability and balling effect. The strength up to a certain limit is increased due to the bridging action of the fibers with the concrete matrix. Individually the minimum compressive strength shown by specimen C2 (3) and maximum is achieved by C2 (2) which is 46.32 MPa. The 3 specimens of each dose are tested and then taken the average of these. The overall maximum strength is achieved by the sample containing 1% steel waste. The maximum cracking strength is shown by specimen C1(2) which is 33.469 MPa that is mentioned above in table no.1. The minimum cracking strength is shown by the specimen CN (3) which is almost 11 MPa. The average cracking strength is also increased up to the dosage of 1% and decreased by adding more dosage of the waste in the specimens due to the same reason that is mentioned above. Figure 3 shows that both the average cracking and ultimate compressive strengths of concrete initially increase with the addition of steel waste fibers, peaking at 1% fiber content. Beyond this point, the strengths decrease, indicating a diminishing return as fiber content increases. Specifically, the highest ultimate compressive strength is achieved at 1%, with subsequent additions leading to a decline, suggesting that 1% steel waste fiber is optimal for enhancing concrete strength.

4 Conclusion

In conclusion, the addition of steel scrap fibers significantly improves the compressive strength of concrete. The concrete cubes with 1% steel waste showed a 39% increase in strength, those with 2% showed a 28% increase, and those with 3% showed a 24% increase. The optimal strength was achieved with 1% steel waste, but higher dosages decreased workability and strength. These findings highlight the importance of precise dosage optimization for enhancing mechanical properties and support sustainable construction practices.

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