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

Characterization and Standardization of Sand for Laboratory Testing in Pakistan

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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 research in Nigeria, Igbokoda sand in 2012 etc. In this research paper, efforts have been made to characterize and standardize sand in Pakistan.

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

2.3 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

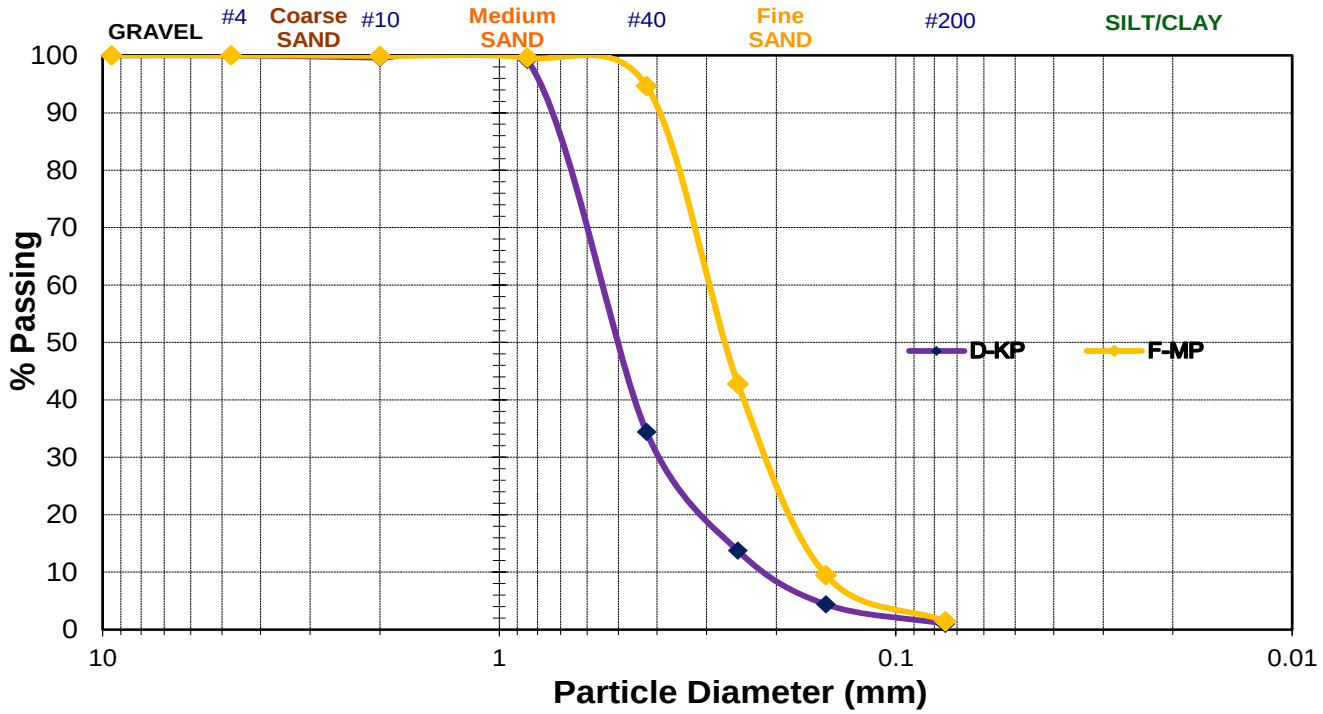

Fig.1 Grain Size Distribution Curve

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	Gs	% 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

3.6 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

3.7 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

3.8 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/N 0.	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.

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