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## The Engineering Properties of Manufactured Sand with Rock Quarry Dust and Muck Material District Jamshoro Sindh Province Pakistan

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### Abstract

Concrete material has widened its scope and usage from natural course and fine aggregates to the manufactured aggregates as the world of construction industry grown up worldwide from ground floor homes to multistory buildings. This was because of availability of good quality aggregates in limited quantity in such regions where the natural aggregate resources are not present in sufficient quantity.

The Jamshoro district of Sindh province Pakistan has huge quantity of exposed sedimentary rocks as limestone, sandstone, shale, and large area of sand deposits which has been used in construction industry throughout the province in very huge quantity for development projects like highways, motorways, bridges, buildings, dams etc. (Figure 1) Keeping view the huge demand the alternate resources like manufactured sand and sweet earth materials are also under observation to use in concrete.

In this research study the impact on the strength of the mixture of sweet earth or mud material concrete have been investigated.

**Keywords:** Manufactured sand; VSI; Gradation or sieve analysis; Sweet earth mud material

### Introduction

Pakistan is a fastly growing developing country after the international cooperation of the different neighboring countries like China, and friendly countries like UAE, Saudi Arabia etc, also the world Bank, Asian Bank and IMF. The large portion of funding was done by China in the name of CPEC (China Pakistan Economic Corridor). A number of projects started in all four provinces of Pakistan specially highways, motorways, buildings of educational institutions and railway tracks including small dams in arid regions were top priority, all these projects needed large quantity of construction aggregates both coarse and fine aggregates.

More than 50% material demand is covered with natural aggregates while remaining 50% is covered with manufactured sand with mixing of allowable sweet earth or mud material in concrete and also in dam embankments, highway subgrade materials [1].

Also the environmental requirements are considered for sand mining to an allowable limit and standards for local people and wildlife habitats.

The number of engineering properties like shape and characteristics of manufactured sand aggregates, allowable proportions for particle packing, shrinkage, raveling and creeping for insuring good quality material.

### Materials and Methods

#### Materials for crushed Sand

The manufactured sand samples were taken from the crusher plants operating in the Jamshoro area around the suburb of the residential town near the large elevated limestone rocks. These rocks are the major source of getting crushed stone and crusher dust for use in concrete and the desirable sizes of coarse aggregates for macadam and asphalt mixes for highway construction etc [2,3].

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**Figure 1:** Photograph of crushing plant manufacturing sand in the Jamshoro district Sindh province Pakistan.

There are number of engineering properties and testing methods for selection of suitable material starting from geological or petrographical, indicating their nature or origin like igneous, sedimentary, metamorphic, texture, surface structure, alteration regarding weathering and erosion hardness, specific gravity, strength, colour and porosity percentage.

Each and every property has its own importance and application [4,5].

The original source material having the basic properties can produce manufactured sand of such resembling nature. All that material must be treated with environmental contamination materials like fine clays, rains, weathering effects etc. The stock piles should not be kept in open ground for months or long, the ideal period is to use within 30 days according to local climate conditions.

### Manufacturing processes of crushed sand

There are number of crushing equipments like rod mills, roll crushers, cone crushers, and impact crushers etc. Manufactured sand involves two main important operations to control the particle shape and gradation during the manufacturing process. A normal crusher plant has a jaw or gyratory crusher called primary crusher and other type of crushers are also used for the required production.

Cone crusher is used in large scale quarries even a tertiary cone stage may be used for final (third or fourth) stage for making cubical fine grained particles; a Vertical Shaft Impactor (VSI) has often been the proper solution [2]. Generally gyratory or cone crushers producing crushed sand of the flabby particle shapes. On the other hand, impact crushers such as hammer mills and rod mills yield excellent cubical shapes. VSI has proved itself to be an effective way of producing cubical (even rounded) particles in the small and medium size fractions (<approx 5 mm). It is a challenge to avoid generating of high percentage of fines. However, the advancement in this field with latest generation of dry screening equipment combined with the latest development of air classification have, enabled to govern the grading curve very precisely, including the finest part [6].

## Test Methods for Manufactured Sand

### Grading and passing 75-micron

Particle size analysis (grading) conducted as per ASTM E2651-19 on manufactured sands (down to the 75-micron size fraction) is useful for determining the total combined particle distribution, which indicates particle packing or voids within a concrete mix. From this perspective, grading is considered a reportable test, and would be specified in a supply agreement for any particular source. For assessment manufactured sand, the grading is a necessary test for

design and quality control of concrete [7].

### Sand equivalent test (ASTM D2419-14)

It is very important to measure the relative proportions of detrimental fine dust or clay-like material in soil or fine aggregates. This test is performed with measured volume of soil or fine aggregate and a small quantity of flocculating solution are poured into a graduated plastic cylinder and are agitated to loosen the clay-like coatings from the sand particles in the test substance. The substance is then processed using additional flocculating solution forcing the clay-like material into suspension above the sand. After a specified sedimentation period, the height of flocculated clay is read and the height of sand in the cylinder is determined. The sand equivalent is defined as the ratio of the height of sand to the height of clay times 100. This test is used to qualify aggregates for applications where sand is desired but fines and dust are not. A higher values of sand equivalent indicates the presence of less clay-like material in a sample [8].

### Durability tests

This test is to determine resistance to disintegration of fine aggregates by saturated sodium sulphate or magnesium sulphate solution can be done as per ASTM D3744/D3744M-18. This test actually provides information which is helpful in assessing the soundness of aggregates subject to weathering action, especially when related information is not available from previous records of the material exposed to actual weathering conditions.

### Mortar trials

In modern technology, curing process is not mostly done while constructing a building and use of cement mortar is very high in bonding the concrete. Curing process need more time, days, and weeks to set the cement mortar bonding between the blocks and to obtain its strength. There rises a need of alternative material in the cement mortar for its internal curing. Specifically selected size of manufactured sand is added and tested for its self-curing process. Thereafter finding the self-curing of the manufactured sand it is added to the cement mortar. By addition of the manufactured sand, the strength of cement mortar increased and the curing process is lowered, which can be obtained through hydration process and by its self-curing process. More, adding of manufactured sand reduced the self-weight to 1.2 times the weight of ordinary cement mortar [9].

## Experimental Investigation

In this study two separate types of manufactured sand has been selected to investigate the effect of effect of compressive strength

i) crushed sand by crushing rock quarry material and ii) crushed sand by crushing quarry rock and muck material [10].

### Materials

The materials used for mix are OPC, manufactured sand blended with 50-50% crushed and VSI sand from rock quarry designated as SCR-1, SCR-2 and SCR-3 and hence forth read as Crushed Sand-I and in another set crushed sand taken from quarry rock and muck material designated as SCR-M-1, SCR-M-2 and SCR-M-3 and hence forth read as Crushed Sand-II, 20 mm and 10 mm size coarse aggregate taken from rock quarry and water reducing admixture. Keeping the grading of crushed sand in Zone-II.

Petrographically rock quarry materials were hard, compact, massive, sedimentary consisting sub-rounded to sub-angular hard

**Table 1:** Showing Four Cement Samples of Different Weeks had been tested for their Physical Properties and Test Results.

SI No	Type of Cement	Normal Consistency	Soundness (mm)	Setting Time (Min)		Fineness (90µ retained)	Compressive Strength (MPa)		
				Initial	Final		03 days	07 days	28 days
1	PPC 18.16	29.5	1.2	124	176	1.58	26.10	34.80	44.20
2	PPC 19.16	29.5	1.1	138	194	1.36	27.8	33.60	46.40
3	PPC 20.16	29.0	1.3	136	179	1.25	24.60	30.30	43.60
4	PPC 21.16	30.0	1.2	146	193	1.23	18.70	29.20	52.00

**Table 2:** Grading of Crushed Sand-I.

Sample no → Sieve ↓	SCR-1	SCR-2	SCR-3	Criteria Limits for Zone-II
10 mm	100	100	100	100
4.75 mm	100	97.65	98.40	90-100
2.36 mm	98.20	77.10	76.20	75-100
1.18 mm	74.20	53.62	52.60	6-100
600 µm	46.20	41.49	43.00	35-59
300 µm	35.40	30.92	36.00	8-30
150 µm	28.20	20.94	26.20	0-20
<75 µm	12.40	13.11	13.56	-
FM	2.97	2.78	2.68	-

**Table 3:** Grading of Crushed Sand -II.

Sample no → Sieve ↓	SCRM-1	SCRM-2	SCRM-3	Criteria Limits for Zone-II
10 mm	100	100	100	100
4.75 mm	98.20	98.61	97.70	90-100
2.36 mm	77.73	79.48	80.30	75-100
1.18 mm	50.97	53.22	62.20	56-100
600 µm	39.38	41.83	42.90	35-59
300 µm	29.99	28.17	25.2	8-30
150 µm	20.72	18.96	10.70	0-20
<75 µm	7.70	10.43	10.04	-
FM	2.83	2.80	2.81	-

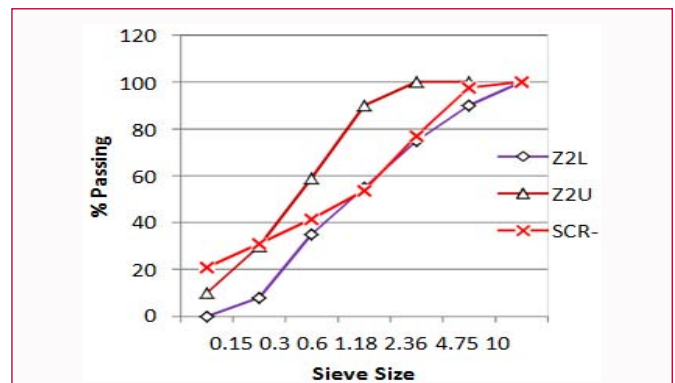
limestones with calcareous sandstones. It consists mainly fine grained quartz and feldspar with minor amount of sericite, biotite, chlorite and iron oxides. Quartz is anhedral to subhedral, fine to medium grained. Some of the quartz grains are recrystallised [11].

The muck material (rock) is mucks tend to be fine-grained, more colloidal, and more decomposed and behave more like inorganic soils because of particle size and a higher percentage of mineral matter, particularly clays.

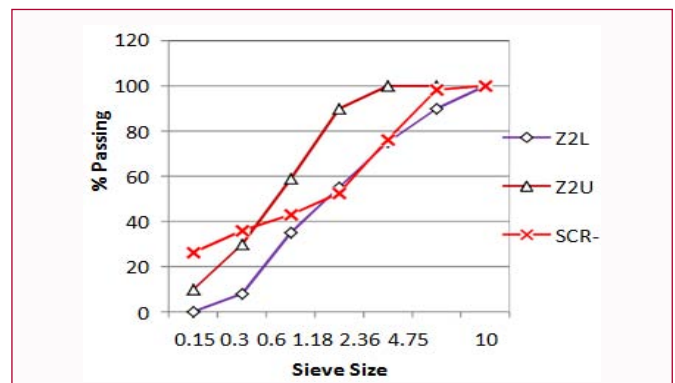
It consists of mainly fine to medium grained quartz and feldspar with some amount of biotite, and muscovite. Biotites occur in the form of fine flakes, along the boundary of quartzo-feldspathic grains (Table 1) [12].

From Table 2 it can be seen that the FM limit varies from 2.68 to 2.97. The corresponding graph for the gradation of SCR-1, SCR-2 and SCR-3 are presented in Figure 2, Figure 3 and Figure 4. Upper and lower limits of the graph represent the boundary limits of Grading Zone-II as per ASTM E2651-19.

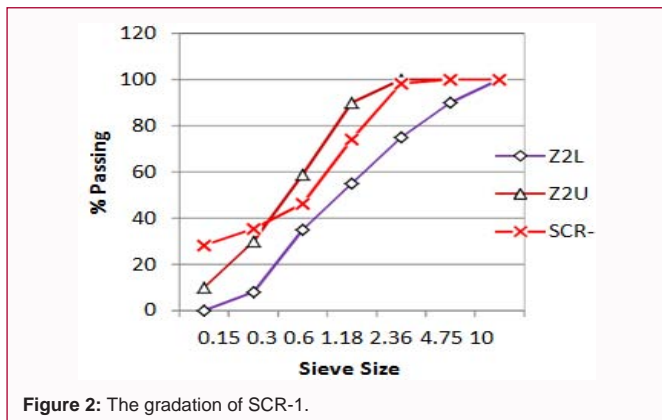
From the above gradation curves it has been observed that in Crushed Sand-I finer fraction (<150 µm) are more than the permissible limit.



**Figure 3:** The gradation of SCR-2.



**Figure 4:** The gradation of SCR-3.



**Figure 2:** The gradation of SCR-1.

From the Table 3, it can be see that the FM limit varies from 2.80 to 2.83. The corresponding graph for the gradation of Crushed Sand-II is presented in Figure 5, Figure 6 and Figure 7. Upper and lower limits of the graph represent boundary limits of Grading Zone-II as per ASTM E2651-19.

From the above gradation curves it has been observed that finer

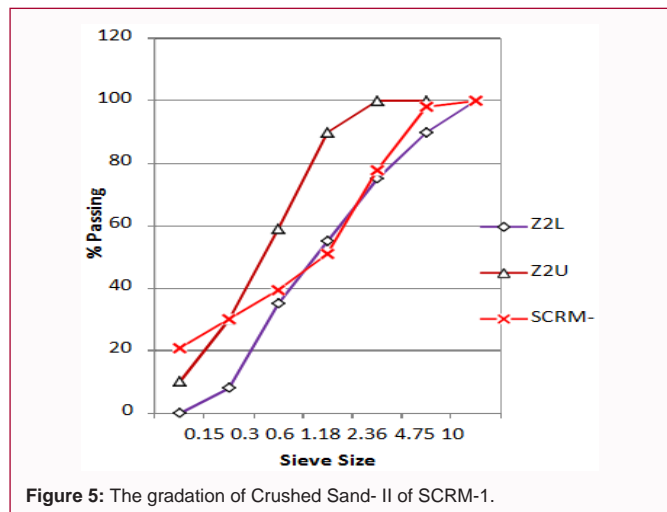


Figure 5: The gradation of Crushed Sand- II of SCRM-1.

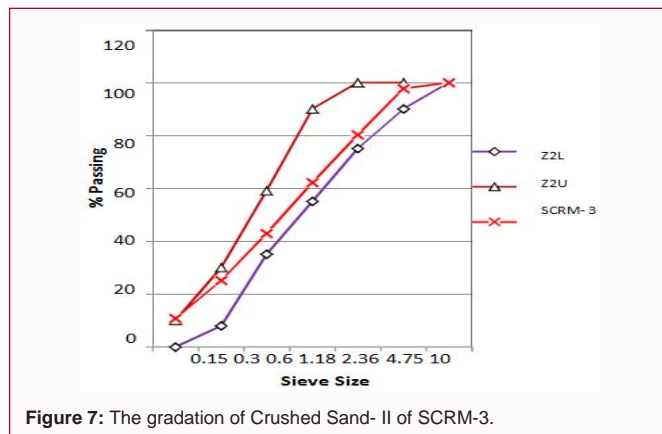


Figure 7: The gradation of Crushed Sand- II of SCRM-3.

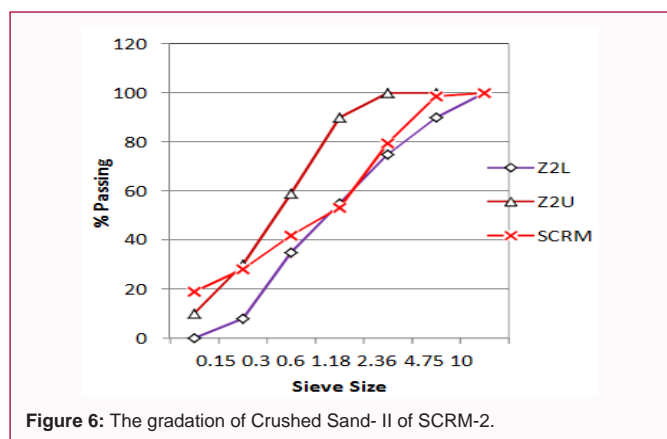


Figure 6: The gradation of Crushed Sand- II of SCRM-2.

fraction (<150 µm) much less than Crushed Sand-I. However, finer fraction (<150 µm) is more than the permissible limit as per ASTM E2651-19 (Table 4,5,6 and 7).

### Discussion

In this research investigation, it has been observed that physical parameters of samples of rock quarry are confirming to wearing surfaces except C-3 and C-8 samples, whereas physical parameters of muck materials are confirming to non-wearing surfaces. Soundness loss of both the samples are comparable and well within the criteria limit as per ASTM E2651-19. An excellent cohesive and consistent

mix was obtained with Crushed Sand-II rather than Crushed Sand-I. This change has happened due to particle shape of the manufactured sand. Shape of the particles of Crushed Sand-II was cube shape whereas Crushed Sand-I was having flaky in nature, cause of which to make consistent mix was difficult/not possible. Remarkable slump loss has been observed while comparing two mixes of the same grade keeping all the variables same. It has also been observed from the sieve analysis that percentage finer than 75 µm fractions is more in the Crushed Sand-I in comparison to Crushed Sand-II [3].

Durability of the concrete depends mostly on permeability, compactability, strength and material quality. In a unit composition of concrete 70-80% volume occupied by aggregate and out of which 30-35% volume occupied by the fine aggregate [6]. As per the test results, it is evident that crushed sand manufactured with quarry and muck materials can be used to produce concrete provided the aggregates (both coarse and fine) from rock quarry, tunnel muck and blended sand meet the physical, chemical and durability criteria especially soundness losses as per ASTM E2651-19.

### Conclusion

It is concluded that though both the crushed sand used in the mixes are comparable in respect of compressive strength of concrete with same cement, aggregate, water cement ratio, admixture type and its doses. Durability study of concrete is required to be checked in longer run for re-use of tunnel muck having high abrasion loss but meeting the requirements for use in non-wearing surfaces as ASTM E2651-19 as a granular material in the form of crushed sand in concrete.

Table 4: The Physical Properties of the Rock Quarry Materials i.e., Specific Gravity, Water Absorption, Flakiness Index, Elongation Index, Soundness Loss, Impact Value, Abrasion Value and Crushing Value.

Sl No	Sample No	Sp Gr	Water Absorption	Flakiness Index	Elongation Index	Soundness Loss	Impact Value	Abrasion Value	Crushing Value
1	C-1	2.68	0.76	12.68	13.17	1.20	22.19	27.20	18.96
2	C-2	2.70	0.57	12.52	13.81	0.85	20.36	27.80	19.36
3	C-3	2.72	0.39	12.11	13.14	1.90	21.84	32.68	20.05
4	C-4	2.68	0.70	11.57	12.71	1.20	19.25	28.54	18.22
5	C-5	2.71	0.52	11.14	13.16	1.00	14.72	20.78	19.65
6	C-6	2.67	0.71	13.30	14.15	1.10	19.90	28.20	25.82
7	C-7	2.70	0.52	11.26	13.14	0.70	14.29	23.36	19.65
8	C-8	2.69	0.54	11.07	14.29	1.05	19.10	30.72	19.37
9	C-9	2.71	0.57	12.12	13.02	1.45	17.10	29.14	18.65
10	C-10	2.70	0.38	13.96	14.92	1.40	20.67	29.64	19.42

**Table 5:** The Physical Properties of the Muck Materials i.e., Specific Gravity, Water Absorption, Flakiness Index, Elongation Index, Soundness Loss, Impact Value, Abrasion Value and Crushing Value.

SI No	Sample No	Sp Gr	Water Absorption	Flakiness Index	Elongation Index	Soundness Loss	Impact Value	Abrasion Value	Crushing Value
1	C-11	2.56	0.75	4.57	5.62	1.60	39.32	50.42	31.87
2	C-12	2.59	1.08	3.32	4.51	1.15	39.12	51.00	32.87
3	C-13	2.59	1.06	3.66	4.71	1.00	40.49	49.42	32.60
4	C-14	2.60	1.10	3.10	4.39	1.15	40.15	51.55	35.22
5	C-15	2.57	1.02	3.58	4.83	1.40	40.02	48.87	33.65
6	C-16	2.61	0.85	4.10	4.96	1.00	38.86	48.61	31.82
7	C-17	2.57	1.00	4.65	5.59	1.60	39.68	50.40	31.65
8	C-18	2.59	1.14	3.84	4.75	1.75	39.16	49.04	31.37
9	C-19	2.61	0.92	3.96	5.10	1.25	39.10	50.26	30.65
10	C-20	2.60	1.08	4.12	5.36	1.25	40.45	51.12	31.42

**Table 6:** Compressive Strength of Concrete of Different Grades using Fine Aggregate as Crushed Sand-I and Quarry Stone as Coarse Aggregate in concrete.

SI No	FM	% Finer than 75 µm	Slump			28 days comp strength		
			M15A20	M25A20	M30A20	M15A20	M25A20	M30A20
1	2.97	12.40	155	150	145	22.13	31.21	36.67
2	2.97	12.40	150	160	140	22.34	30.40	36.58
3	2.97	12.40	160	150	160	22.55	29.88	36.90
4	2.78	13.11	150	155	145	22.37	30.03	36.87
5	2.78	13.11	155	160	160	22.07	30.34	36.72
6	2.78	13.11	150	160	160	22.86	30.33	36.84
7	2.68	13.56	150	150	150	22.59	30.47	36.95
8	2.68	13.56	155	160	160	22.73	30.41	36.13
9	2.68	13.56	155	150	160	22.74	30.47	36.21

**Table 7:** Compressive Strength of Concrete of Different Grades using Fine Aggregate as Crushed Sand-II and Quarry Stone as Coarse Aggregate in concrete.

SI No	FM	% Finer than 75µm	Slump			28 days comp strength		
			M15A20	M25A20	M30A20	M15A20	M25A20	M30A20
1	2.81	7.70	135	140	145	22.68	31.24	36.84
2	2.81	7.70	140	140	140	22.58	31.42	36.87
3	2.81	7.70	140	150	150	22.76	31.0	36.74
4	2.80	10.43	140	150	150	22.50	36.76	36.90
5	2.80	10.43	140	155	140	22.69	30.95	37.04
6	2.80	10.43	145	145	150	22.80	31.32	37.23
7	2.83	10.04	140	140	145	22.93	31.29	37.11
8	2.83	10.04	140	155	145	22.73	31.56	37.32
9	2.83	10.04	140	140	150	22.68	31.17	36.58

The manufactured sand produced with the help of proper machines can be a better substitute to river sand. The sand must be of suitable gradation (it should have particles from 150 microns to 4.75 mm in proper proportion). When fine particles are in proper proportion, the sand has fewer voids. The cement quantity required will be less. Such sand will be more economical. The construction industry seeks for manufactured fine aggregates for making concrete is increasing day by day as river sand cannot meet the rising demand of construction sector. The process of formation of natural river

sand takes millions of years to form. Considering, the increasing demand and acute shortage of river sand, huge short coming on quality of river sand, high cost, greater impact on road damages and environmental effects. The construction industry should start using the manufactured sand to full extent as alternative, reduce the impacts on environment by not using the river sand. The Local Authorities/ Public Works Department/ Government, should encourage the use of manufactured sand in public construction works, if possible, should make mandatory to use manufactured sand wherever available with immediate effect. The government should come out with, Policy on Sand-encourage the industry people to set up more number of sand crushing units across all districts, States to meet the sand requirements of the construction industry.

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