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Evaluation of Experimental Datasets on Physical properties of Natural Sands and Crushed Sand

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ABSTRACT: Sand, as one of the most accessible natural resources with its in built chemical inertness and hardness properties, has been commonly used as a construction material since the earliest days of civilization. It is a granular material formed from fine breakdown of rocks and minerals due to environmental and weathering effect. The composition of sand depends on its parent rock, environmental conditions and process of weathering under it has gone. Use of sea sand in comparison to river sand was not preferred due to the high chloride content in sea sand which leads to weakening structures and structural integrity. Scarcity of river sand due to uncontrolled extraction, urban expansion, its transportation from long distance adds to its cost etc has forced legislations and environmental constraints. Therefore it is time demand to find substitute to river sand for various construction activity. Use of Crushed sand as an alternative to meet the growing demand is in practice. The experimental data explores the assessment of the quality of crushed sand in replacement of sea sand and river sand. Experimental tests carried out on three sand includes pH , specific gravity, moisture content, bulk density, bulking of sand, sieve analysis, SEM-Edax, XRD. Thus the objective of paper is to conduct these tests and present the experimental datasets in tabular format after its Evaluation. This paper contribute technical comparison of these three sand and convey suitability of crushed as a alternative to river and sea sand.

Keywords: Crushed Sand, IS, River Sand, Sea sand, Strength, Test.

I. INTRODUCTION

Sand is a granular material formed from fine breakdown of rocks and minerals due to environmental and weathering effect. The composition of sand depends on its parent rock environmental conditions and process of weathering under it has gone. The major constituent are silica (silicon dioxide, or SiO_2), calcium carbonate, River sand, Beach sand, Marine sand, Sand dunes, Coral Sand, Glass Sand, Immature Sand, Gypsum Sand, Ooid sand, Silica sand, Quartz Sand will have different dominating constituents and their properties for use. Sea sand is not a preferred choice in construction industry due to many reasons. To mention few, high content of chloride in sea sand leads humidity which causes erosion and rusting in the steel.

Sand Gradation: As per geologist, size of sand particle ranges from 0.0625 to 2mm. Sand grain represent individual particle size. Depending on grain size it is known as gravel (2 mm up to 64 mm) and silt (0.0625 mm down to 0.004 mm). In 20th century, Albert Atterberg standard considered smaller particle less than 0.02mm as sand. United States Department of Agriculture in 1938 has referred minimum size of sand as 0.05mm while in 1953, American Association of State Highway and Transportation Officials modified it up to 0.074mm. The International Organization for Standardization (ISO 14688) defined grades of sand as coarse (above 2mm), medium (0.63 to 2mm) and fine (0.063 to 0.2mm). United States classifies sand in five grades as very coarse (1 – 2mm), coarse (0.5 – 1mm), medium (0.25 – 0.5mm), fine (0.125 – 0.25mm) and very fine (0.0625 – 0.125mm).

Mineral composition: The major and common constituent found in sand from inland continental and non-tropical seashore area is the silica (silicon dioxide, or SiO_2) in the form of quartz. Quartz minerals are resistant to weathering due to inherent chemical inertness and considerable hardness,. The composition of sand depends on its parent rock and environmental conditions and process of weathering under it has gone. The bright white sands formed due to erosion of limestone are widely found in tropical and subtropical coastal areas. This sand may contain coral and shellfish fragments indicating existence of living organisms. National Monument in New Mexico is famous example of gypsum sand dunes of the White Sands. Arkose or sandstone contains feldspar are formed due to continuous weathering and erosion of granitic rock outcrop. Magnetite, chlorite, glauconite or gypsum is also found in some sand. The black in colour sands derived from volcanic basalts and obsidian are rich in magnetite. Sands derived from basaltic (lava) are green in colour and contains Chlorite-glauconite. Deep yellow colour sand found in Southern Europe has iron impurities within the quartz crystals of the sand. Existence of garnets, gemstones are also found in sand. Analysis of Tapti River by XRD and SEM shows presence of Quartz, Kaolinites, Calcite, Vermiculite, Polygorskite, Micas and Gibbsite [1]. Sand, as one of the most accessible natural resources with its in built Chemical inertness and hardness properties, it has been used commonly as a construction material since the earliest days of civilization. Use of sea sand in cement concrete production, brick production was made by many countries. However use of sea sand in

comparison to river sand was not preferred due to the high chloride content in sea sand which leads to weakening structures and structural integrity. Presence of chloride content in the sand contributes to the brittleness of the brick [2]. Also illegal use of high-chloride construction material creates safety hazards to the end users [3]. Studied amounts of chloride (Cl^-) and sodium (Na) ions in seawater as mentioned in Table 1.

Table 1: Chloride content in sea water.

Ion	Grams per 1000g seawater	Mass %
Cl-	19	1.9
Na+	10.7	1.07
SO42-	2.7	0.27
Mg2+	1.3	0.13
Ca2+	0.4	0.04
K+	0.4	0.04

Another natural resource used for civil engineering construction is the river sand. River sand is obtained by dredging from river beds. River sand particle are rounded and smooth because it has been subjected to years of abrasion. Also it has very low silt and clay contents due to its washing over the years. River sand being locally available, cheap and harmless. These factors make river sand as preferential choice over sea sand for construction. On the other hand uncontrolled extraction of sand leads to depletion of river, causing environmental concern and economic losses to adjacent land.

Nowadays due to shortage and restriction on use of river sand, intentionally rocks are crushed or broken down to desired sizes as a substitute to natural sand. Such sand are referred as Artificial or Manufactured or Crushed sand [4, 5]. The requirement of particle size distribution of crushed sand for various application in construction can be controlled at crushing plant.

The objective of this paper is to investigate and compare engineering properties of Sea sand, river sand and crushed sand in view of usage in construction.

II. MATERIALS AND METHODS

Sand sample are collected from various location as mentioned in Table 2 from Maharashtra.

Table 2: Location of sand samples.

S. No.	Sample	Location	Latitude	Departure
1.	River Sand	Bhima river Indapur	18.30337	74.762706
2.	Crushed sand	Katrajghat, Pune-	18.420924	73.856208
3.	Sea Sand	Diveaagar Beach	18.170445	72.985772

A. pH Test

pH is indicative measure of the acidity or basicity of an aqueous solution. Pure water has a pH 7, and acidic solutions have pH less than 7 while basic or alkaline solution have a pH greater than 7. The pH is determined using a buffer solution of 4, 7, 10, distilled water, Calcium Chloride Solution, 0.01M and a PH meter which indicates the value once the electrode is dipped in the solution whose PH is to be determined.

The PH test for three types of sand was conducted by taking six beakers each containing 30, 60, 40, 80, 50, 100 ml of distilled water (pH=7). The beakers contained 30, 40 and 50g of sand. The solution was prepared for three types of sand and the PH was calculated using a PH meter by dipping the electrode into the solution. The buffer solution used in this case was a mixture of ammonium chloride (NH_4Cl) and ammonium hydroxide (NH_4OH) which had a PH value of 4.7 and 10. For better quality pH was also determined by using 0.01M $CaCl_2$ in place of distilled water. The test results are shown in Table 3.

Table 3: pH of Sea, River and Crushed sand

(a) Sea sand.

Sea sand	30 g		40 g		50 g		Avg
Distilled Water (ml)	30	60	40	80	50	100	
pH	8.01	8.96	8.62	8.17	7.92	7.85	8.255
0.01M CaCl2 (ml)	30	60	40	80	50	100	
pH	8.68	8.43	8.88	7.94	8	8.12	8.34
Average pH8.3							

(b) River sand.

River sand	30 g		40 g		50 g		Avg
Distilled Water (ml)	30	60	40	80	50	100	
pH	7.97	7.88	8.01	7.97	8.17	8.45	8.075
0.01M CaCl2 (ml)	30	60	40	80	50	100	
pH	7.76	7.61	7.81	7.66	7.85	7.8	7.75
Average pH7.91							

(c) Crushed sand.

Crushed sand	30 g		40 g		50 g		Avg
Distilled Water (ml)	30	60	40	80	50	100	
pH	7.83	7.98	7.64	7.72	7.82	7.69	7.78
0.01M CaCl2 (ml)	30	60	40	80	50	100	
pH	7.78	7.92	7.5	7.86	7.28	7.84	7.61
Average pH7.695							

B. Specific Gravity

Specific Gravity of three types of sand was determined as per IS 2720 -1980 (Part III).Average of triplicate reading was noted as specific gravity of a sand. The results are tabulated in Table 4.

Table 4: Specific Gravity.

(a) Sea Sand.

P_1	P_2	P_3 (g)	P_4 (g)	P_5 (g)	P_6 (g)	P_7 (g)	P_8
1	1	51.844	70.278	123.923	112.4	18.434	2.667
2	1	51.844	69.893	123.936	112.4	18.049	2.771
3	2	53.352	70.214	125.194	115.17	16.862	2.466
4	2	53.352	70.873	125.822	115.17	17.521	2.551
Average Specific gravity : 2.61							

(b) River Sand.

P_1	P_2	P_3 (g)	P_4 (g)	P_5 (g)	P_6 (g)	P_7 (g)	P_8
1	1	51.844	69.243	123.16	112.4	17.399	2.621
2	1	51.844	68.968	123.216	112.4	17.124	2.715
3	2	53.352	67.253	124.184	115.17	13.901	2.844
4	2	53.352	67.056	123.323	115.17	13.704	2.469
Average Specific gravity : 2.66							

(c) Crushed Sand.

P_1	P_2	P_3 (g)	P_4 (g)	P_5 (g)	P_6 (g)	P_7 (g)	P_8
1	1	51.844	70.357	124.076	112.4	18.513	2.708
2	1	51.844	71.744	124.749	112.4	19.9	2.635
3	2	53.352	71.334	127.03	115.17	17.982	2.937
4	2	53.352	70.195	125.331	115.17	16.843	2.521
Average Specific gravity : 2.70							

Where P1 - Trial No., P2 - Bottle No, P3 - Empty mass of Specific gravity bottle, P4 - Mass of Specific gravity bottle + soil, P5 - Mass of Specific gravity bottle + soil + water, P6 - Mass of Specific gravity bottle + water, P7 - Mass of oven dry soil, P8- Specific gravity**.**

C. Moisture Content

A representative sample of each sand sample is taken from the stock and weighed. This sample is dried in oven and weighed. Absorbed moisture is that which is actually absorbed by the sample and free moisture content is that which is on the surface of sand. The test results are tabulated in Table 5.

Table 5: % Moisture Content.

(a) Sea Sand.

W1(g)	W2(g)	W3(g)	(W2-W3)	(W3-W1)	% M. C
40	79.5	78.3	1.2	38.3	3.13
40	81.2	79.8	1.4	39.8	3.51
40	80.1	78.9	1.2	38.9	3.10
Average % Moisture Content3.246					

(b) River Sand

W1(g)	W2(g)	W3(g)	(W2-W3)	(W3-W1)	% M. C
40	78.4	77.5	0.9	37.5	2.4
40	77.8	76.8	1	36.8	2.72
40	79.2	78.4	0.8	38.4	2.10
Average % Moisture Content					2.40

(c) Crushed Sand.

W1(g)	W2(g)	W3(g)	(W2-W3)	(W3-W1)	% M. C
40	81.2	79.1	2.1	39.1	5.37
40	80.8	78.8	2	38.8	5.15
40	80.1	78.3	1.8	38.3	4.7
Average % Moisture Content					5.07

W1 - Mass of container, W2 - Mass of container with wet soil, W3 - Mass of container with dry soil.

D. Loose Bulk Density and Tapped Bulk Density % Voids

Bulk density can be calculated by various methods [6]. This test for bulk densities and calculation of % voids was conducted as per IS 2386-1963 (Part III) Standard cylindrical metal measure of three litre capacity was filled by scoop from a height not more than 50mm above the top of the measure with due care to prevent segregation of the particle sizes of which the sample is composed. The surface of the sand was levelled using straight edge. The net weight of the sand in the measure was determined and the loose bulk density calculated in g/cc.

In case of Taped or Rodded or Compacted weight, metal measure was filled about one-third full of sand and tamped with 25 strokes of the rounded end of the tamping rod. This step was repeated two time to fill the metal measure up to its full capacity. Excess sand was strucked off, using the tamping rod, and the net weight of the sand was noted to find Rodded bulk density in g/cc. The results of loose and Rodded bulk densities are shown in Table 6 and 7 respectively. The % voids are calculated as per following equation.

Percentage voids = (Gs– γ) / Gs

Where Gs is the specific gravity of sand and γ –bulk density.

Percentage voids in sea sand, river sand and crushed sand was observed as 40.42, 39.17 and 38.14 respectively. Test for both these bulk densities and calculation of % voids was as per IS 2386- 1963 (Part III).

Table 6: Loose Bulk Density.

	Sea sand			River sand			Crushed sand		
W1	2686	2686	2686	2686	2686	2686	2686	2686	2686
W2	7315	7390	7353	7515	7460	7589	7680	7736	7640
W3	4629	4704	4667	4829	4774	4903	4994	5050	4954
V	3000	3000	3000	3000	3000	3000	3000	3000	3000
γL	1.543	1.568	1.556	1.61	1.591	1.634	1.6647	1.683	1.651
Avg	1.555			1.618			1.67		

Table 7: Tapped Bulk Density.

	Sea sand			River sand			Crushed sand		
W1	2686	2686	2686	2686	2686	2686	2686	2686	2686
W2	7505	7473	7453	7515	7460	7589	7680	7736	7640
W3	4819	4787	4767	4829	4774	4903	4994	5050	4954
V	3000	3000	3000	3000	3000	3000	3000	3000	3000
γL	1.606	1.596	1.589	1.61	1.591	1.634	1.6647	1.683	1.651
Avg	1.597			1.706			1.71		

W1 - Mass of density container (g), W2 - Mass of density container with sand(g), W3 – Net Mass of sand(g), V - Volume of density container in cc, γL - Bulk Density (g/cc)

E. Bulking of Sand

The moisture in sand causes formation of water film around sand particles which results in the increase of volume of sand. Highest increase in volume occurs in fine sand and minimum in coarser sand. Increase in the moisture content of sand due to addition of water, results in packing of the sand particles near each other resulting in decrease of bulking of sand. Dry sand of 300g was added with incremental % of water. The maximum bulking of sea, river and crushed sand was 37.5%, 31.17% and 18.83% at 15, 18 and 12g of water addition respectively as seen from Fig.1. This test was conducted as per IS 2386 (1963) Part 3.

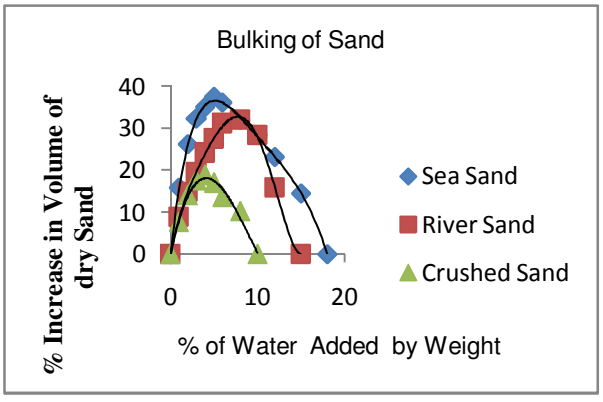

Fig. 1. Chart showing bulking of sand.

F. Sieve Analysis

Test is conducted on dry sample to determine the grain size distribution and zoning of grad of sand as per IS 2386(PART I): 1963 and IS 386-(2016) respectively. The grain size distribution is shown in Fig. 2. Outcome of the result indicate that sea sand falls in grading zone (IV), which is not suitable to use as fine aggregate for concrete. River sand and Crushed sand falls in grading zone (III) and grading zone (I) respectively.

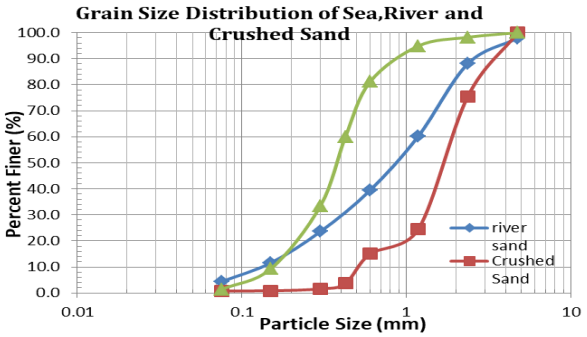

Fig. 2. Grain size Distribution.

G. Morphology and Elemental composition

Morphology (Fig. 3) of three sand was understood from SEM images. Also the elemental composition (Fig. 4) indicates % variation in chemical composition of three sand.

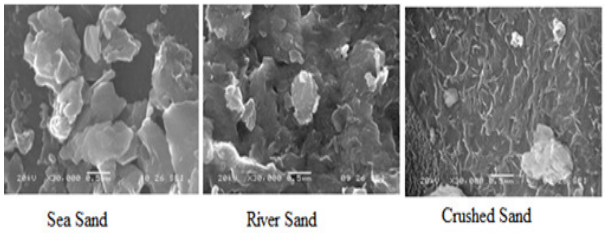

Fig. 3. SEM-Images.

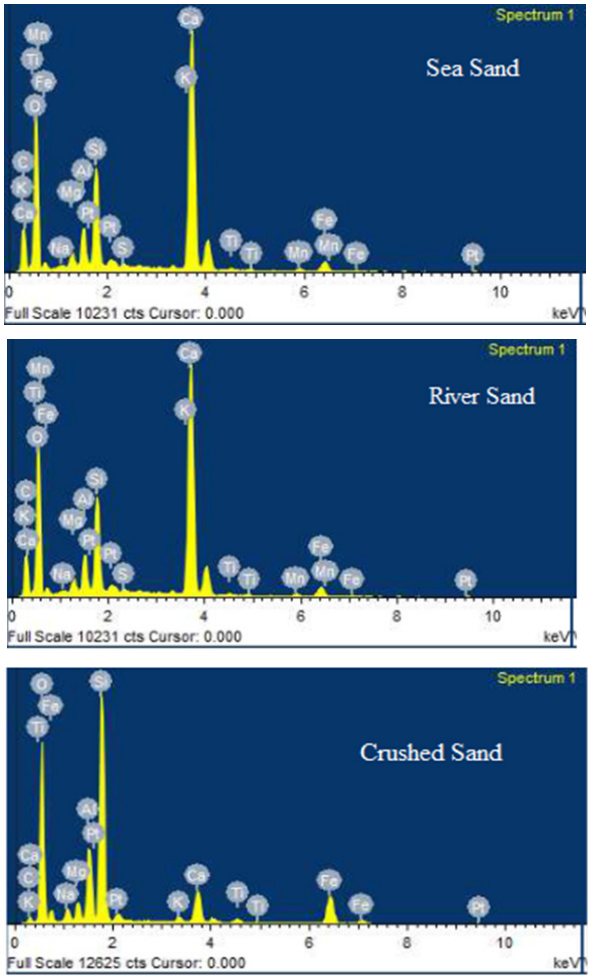

Fig. 4. EDX Spectra.

H. Compressive Strength

Compressive strength of concrete cubes was determined as per IS 516(1959). In this, cubes were made from Ordinary Portland cement (OPC) grade 53, and sand sample mixed in 1:3 proportion and cured for 3, 7, 14, 21, 28 days. The results of compressive strength were in line with the requirement of IS. Fig. 5 showed differences in compressive strength of the samples used. It is observed that river sand has highest compressive strength value as compared to other two sand. The outcome of the strength test revealed the performance and standard of three types of sand for construction activities.

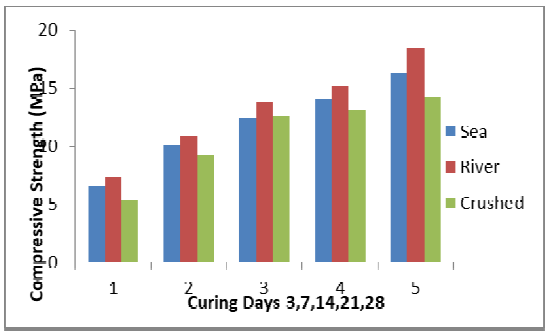

Fig. 5. Compressive Strength.

III. RESULTS AND DISCUSSION

Summary of the test conducted on these three types of sand is shown in Table 8.

Table 8: Summary of Test Results.

Summary of Physical Properties of Sand				
S. No.	**Test**	**Sea Sand**	**River Sand**	**Crushed Sand**
1.	pH	8.2	7.91	7.695
2.	Specific Gravity	2.61	2.66	2.7
3.	Moisture Content	3.245	2.4	5.07
4.	Loose Bulk Density	1.555	1.618	1.67
5.	Tapped Bulk Density	1.597	1.706	1.71
6.	Bulking of Sand	37.5	32	18.83
7.	Sieve Analysis	Grad IV	Grad III	Grad I
8.	Compressive Strength at 28 days (Mpa)	16.29	18.48	14.28

The pH test revealed the highly alkalinity of the sea sand in comparison to river sand crushed sand. This could be due to the salts present in the sea sand. This is the only reason for which sea sand is not preferred for construction purpose in spite of its abundant availability. Specific gravity ranges from 2.61 to 2.7 and are within permissible values and are comparable. Moisture content will vary depending on the status of sand at the time of testing. The difference in loose and tapped bulk density is indicative of free flow characteristics. The overall inference drawn from the bulk and tap density values reveal that the river sand has poor flow characteristics, as compared to sea and crushed sand. Sea sand and crushed sand has very low difference between bulk and tap density values and hence has free flow characteristics. Bulking of Sand indicates volumetric variation due to moisture present in sand. Test result revealed that Sea sand has higher volumetric change as compared to other sand. From the sieve analysis we see that crushed sand is slightly coarser than the natural sand and falls in zone I. While river and sea sand falls under zone (IV) and zone (IV). Obtained results for moisture content, specific gravity, bulk density are in line with those obtained by [7] and also within limits mentioned by respective IS. It was observed from the compression test that the river sand has highest compressive strength and lowest for crushed sand even though all three types of mortar blocks were made under same conditions and parameters.

IV. CONCLUSION

Based on test result obtained following conclusion are drawn.

– All three types of sand could be used for construction activity.

– Use of crushed sand as an alternative to river and sea sand is possible since its results has comparable properties with natural sand and are within the range specifies by the Indian standard code of practice

– Crushed sand is cheaper and cost effective in the market where as natural sand is scarcely available.

V. FUTURE SCOPE

It is time to have additional study on crushed sand to make it useable in construction industry to avoid dependability of river sand. Further study on durability of structures which are constructed by crushed sand needs to be evaluated.

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Conflict of Interest. No Conflict of interest.

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