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Study on Mechanical Properties of High Performance Concrete using M-Sand

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Abstract

Background/Objectives: National Green Tribunal which has taken cognisance of this and has enforced severe restrictions on sand mining from river beds and relevant laws for obtaining licence have been made very stringent. Hence there is a need to look for alternatives to river sand without sacrificing performance of concrete/mortar. **Methods/Statistical Analysis**: In this work, experimentally investigate the effect of M-sand in concrete by replacing the river sand (0%, 25%, 50%, 75% and 100%) and develop a high performance high strength concrete with target strength of 40MPa. **Findings:** The investigations are carried out to study the effect of M-sand on mechanical properties of concrete such as Compression, Tensile and Flexural Strength at the age of 3, 7, 28 and 56 days. Result shows that, there is a liner increase in compressive strength with the replacement of 0 to 100% river sand by M-sand. Replacement of 100% of river sand by M-Sand induced higher compressive, split tensile and flexural strength at the end of 28 days. The increase in strength was in the order of 12-18% as compared to concrete with river sand. Similar results also showed an increase in the strength parameters at the longer duration of curing periods. **Applications:** Studies revealed that, the use of M-sand in concrete for the construction purpose is acceptable for the concrete of grade upto M40 and also reduce the exploitation of river sand.

Keywords: Compressive Strength, Flexural Strength, Flyash, M-Sand, Split Tensile Strength

1. Introduction

Construction sector is one of the highest consumers of natural resources and energy amongst the various industries. It is now being increasingly realised in the construction industry that sustainable development concepts can enhance both the economic well-being and environmental health of communities and the benefits include resource and energy efficiency, healthy buildings and materials, ecologically and socially sensitive land use, transportation efficiency and strengthened local economics and communities. In the World, concrete is one of the major building materials used in the construction industry. About 35-40% volume of sand is used in the manufacture of concrete. The river sand used in concrete is one of cheapest natural resource. However, the excessive mining of sand from the river bed has led to the depletion of natural river bed in the developing country like India facing shortage in good quality natural sand[1,2]. Hence there is a need to look for alternatives to river sand without sacrificing durability of concrete/mortar. There are many alternatives to river sand are considered by the researchers. Some of them are; Manufactured Sand (M Sand), Copper slag sand, Processed Quarry Dust[3], Process Crushed Rock Fines (CRF)[4], Dune Sand[5], Offshore Sand[6], Washed Soil (Filtered Sand), Fly ash/Bottom ash/Pond ash, Construction demolition waste, Granite fines/Slurry, Powdered glass, Aluminium saw mill waste, etc. Studies carried out the effect of high levels of fines content and quarry waste on concrete properties. Proportioning of concrete mixes with rock dust is considered as a fine aggregate[1,2,7]. Environmentalists alarm the excessive sand mining from river beds. Due to these environmental issues Indian government has banned the mining of sand from

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river beds. Hence the natural sand has become very costlier and the availability has become very scarce. The silt and clay has been found abundantly in the natural sand and the sand available is also very coarse. These fine materials reduce the strength and durability of concrete. These factors have resulted in finding an alternative solution for the construction industry to bank on Manufactured Sand (M-Sand). It is the most suitable one to replace river sand. M-Sand available is graded, sieved and washed while compared to river sand. M-sand particles are more rounded, granular and do not have sharp edges. Hence, the defects such as honey combing, segregation can be avoided during concreting. Experimental studies were conducted by various researchers to use the M sand as fine aggregate in mortar and concrete as a partial and full replacement for river sand[8–10].

Based on the literature review, the researchers have focussed on the usage of M Sand as an alternative to river sand to find the optimal percent of replacement for obtaining maximum compressive strength, higher tensile and flexural strength with Ordinary Portland Cement (OPC) and Supplementary Cementitious Materials (SCM) such as silica fume, RHA etc. To solve the problem an alternate to river sand is more essential in the present situations. Manufactured sand which is a processed product of fine aggregate form various rock sources is the most suitable and economically viable option. Although the practice of using manufactured sand has been there for quite a while it is only used in the lower grades of concrete. To use manufactured sand in high grade concrete of M40 and compare with the river sand in strength parameters will be helpful in understanding the usage of manufactured sand in high strength high performance concrete. In this study the attempt is made to study the high strength characteristics of concrete (M40) using M sand as fine aggregate in concrete with the partial and full replacement. The objective of the present work is to study the effect of percentage replacement of manufactured sand by river sand as 0%, 25%, 50%, 75%, 100%. This study was carried out on M40 grade of concrete with 0.41 water cement ratio.

2. Experimental Programme

2.1 Materials Used

Cement used was Type I Portland cement conforming to Indian Standard IS:12269[11]. The fly ash used was Class F fly ash confirming to ASTM Standards. The physical properties and the chemical composition of the material used are shown in Table 1. Coarse aggregate with a maximum size of 12mm and a specific gravity of 2.86 was used in Saturated Surface Dry (SSD) condition. The aggregate gradations fall within the limits of ASTM C33[12] standard. Fine aggregate complying with ASTM C33 gradation limits possessing a fineness modulus of 2.5 and a specific gravity of 2.57 was also utilized in SSD condition. Manufactured Sand possessing a fineness modulus of 3.0 and specific gravity of 2.78 is used in this study. The particle size distribution of river sand and M Sand along with upper and lower limits of zone II of IS:383[13] requirements is presented in Figure 1. Due to low water requirement, high cement content and the absence of larger coarse aggregate content, the efficient mixing of high strength concrete is more difficult than conventional concrete. For these reasons, a poly carboxylic ether based superplasticizer with a solid content of 40% was used and the mixing time was increased to produce uniform concrete without any segregation.

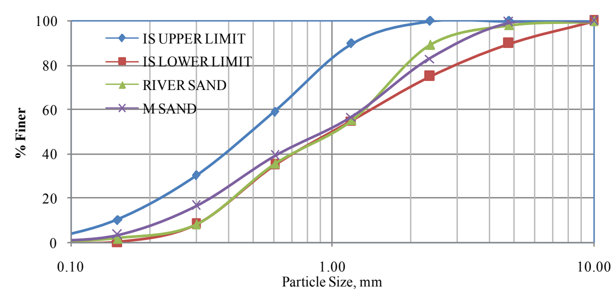

Figure 1. Particle size distribution for River Sand, M Sand and IS Limits.

2.2 Mix Proportions

HPC mixes were designed initially by following the procedure as described in the proposed method by IS:10262[14]. This method is based on the calculation of the composition of non air-entrained HPC. The method itself is very simple. It follows the same approach as ACI 211-1, Standard Practice for Selection Proportions for normal, heavy weight and mass concrete[15]. This method is a combination of empirical results and mathematical calculations based on the absolute volume method. Trial mixtures were prepared to obtain target strength of 40 MPa at 28 days. The dosage of superplasticizer was estimated to maintain the slump around 100mm. The detailed mixture proportions for the study are presented in Table 2.

Table 1. Physical properties and chemical composition of cementitious materials

Properties	OPC	FlyAsh
Type/Class	IS-12269-1987	ASTM Class F
Physical Properties		
Specific Gravity	3.10	2.16
Fineness		
Passing 45μm sieve (%)	-	90%
Retained on 150μm sieve (%)	-	1%
Surface Area, Blaine's (cm^2/gm)	2746	3683
Chemical Analysis		
SiO_2	22.38	61.85
Al_2O_3	6.73	28.03
Fe_2O_3	4.72	5.03
CaO	59.46	1.06
MgO	1.02	1.05
SO_3	2.33	0.07
Na_2O	0.021	0.21
K_2O	0.36	1.34
Cl	0.00	0.001
LOI	2.31	0.95

Note: OPC, Ordinary Portland Cement; LOI, Loss on ignition

Table 2. Concrete mix proportions

Ingredients	Mix Designation				
	M1	M2	M3	M4	M5
Cement, kg/m^3	283.5	283.5	283.5	283.5	283.5
Flyash, kg/m^3	94.5	94.5	94.5	94.5	94.5
Fine Aggregate, kg/m^3	951	713.25	475.5	237.75	-
M. Sand, kg/m^3	-	237.75	475.5	713.25	951
Coarse Aggregate, kg/m^3	979	979	979	979	979
Water, Lts/m^3	155	155	155	155	155
SP, Lts/m^3	3.45	3.45	3.45	3.45	3.45
Slump (mm)	100	110	115	115	115

2.3 Specimen Preparation

Coarse, fine aggregates and river sand were mixed for one minute in a mixer. Cement, and flyash was added to the mix and the materials were mixed for another minute. The required super plasticizer was poured into the total water outside the mixer, and the solution was added to the mix gradually for a period of three minutes. At this stage, the slump test was performed according to ASTM C143[16] standard. Fresh concrete was cast in steel moulds and compacted on a vibrating table. After pouring the mix into oiled moulds, a vibrator was used to decrease the amount of air bubbles. The specimens were demoulded after 1 day and then placed in a curing room with 90% relative humidity and 23ºC for 27 days of curing. For 12 hours prior to the tests, the specimens were allowed to air dry in the laboratory.

3 Results and Discussion

3.1 Compressive Strength

The compression test was carried out on cubes cast for the various trial mixes. The compression strength is a measure of the concrete's ability to resist loads which tend to crush it. The cube was placed in the compression testing machine and the load was applied without shock and increased continuously at the rate of 140 kg/cm^2 until cracks were observed on the concrete surface and cube failed to take further load. Table 3 shows the cube compressive strength of trial mixes at 3, 7, 28 and 56 days. The bar chart showing the increase in compressive strength for various mixes is shown in Figure 2. Concrete mixes revealed an increase of upto 27.3% in compressive strength as a result of replacement of manufactured sand up to 100% as seen in Table 3 compared to controlled concrete at the end of 28 days.

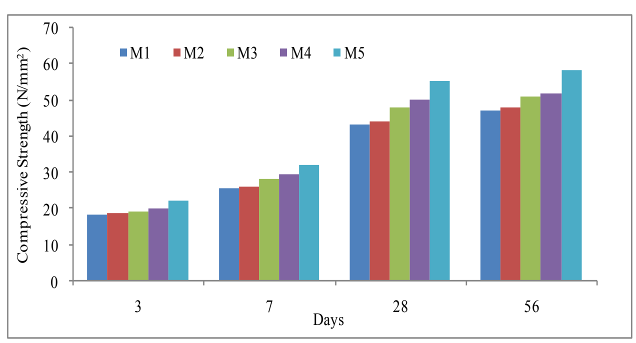

Figure 2. Variations in compressive strength of concrete.

3.2 Split Tensile Strength

In this method, the concrete cylindrical specimens of various trial mixes were placed horizontally between the

Table 3. Compressive test results of concrete

S.No	Mix Designation	Days	Compressive Strength (MPa)	% increase in Compressive Strength
1.	M1	3	18.6	-
		7	25.6	-
		28	43.43	-
		56	47.2	-
2.	M2	3	18.8	1.08
		7	26.3	2.73
		28	44.2	1.78
		56	48.3	2.33
3.	M3	3	19.3	3.76
		7	28.2	10.16
		28	48.3	11.21
		56	51.3	8.69
4.	M4	3	24.2	8.60
		7	29.6	15.63
		28	50.2	15.59
		56	52.1	10.38
5.	M5	3	22.3	19.89
		7	32.2	25.78
		28	55.3	27.33
		56	58.4	23.73

loading surfaces of the compression testing machine and load was applied until the failure of the cylinder, along the vertical diameter. This test gives more uniform results than other tension tests. Strength determined from splitting test is believed to be closer to the true tensile strength of concrete, than the modulus of rupture. Tensile strength is one of the basic and important properties of concrete and is required for the design of concrete structural elements subjected to transverse shear, torsion, shrinkage and temperature effects. Table 4 gives the split tensile values of cylinders for various mixes at 3, 7, 28 and 56 days respectively. The bar chart showing the increase in split tensile strength for various mixes is shown in Figure

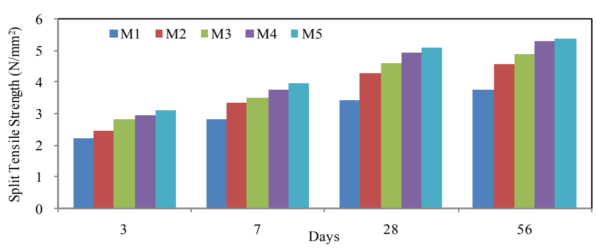

Figure 3. Variation in split tensile strength of concrete.

3. The test was conducted as per IS:5816[17]. Concrete mixes revealed an increase of upto 47.83% in split tensile strength as a result of replacement of manufactured sand up to 100% as seen in Table 4 compared to controlled concrete at the end of 28 days.

Table 4. Split tensile test results of concrete

S.No	Mix Designation	Days	Split Tensile Strength (MPa)	% increase in Split Tensile Strength
1.	M1	3	2.2	-
		7	2.8	-
		28	3.45	-
		56	3.75	-
2.	M2	3	2.45	11.36
		7	3.33	18.93
		28	4.28	24.06
		56	4.59	22.40
3.	M3	3	2.8	27.27
		7	3.5	25
		28	4.6	33.33
		56	4.89	30.4
4.	M4	3	2.95	34.09
		7	3.75	33.93
		28	4.95	43.48
		56	5.29	41.07
5.	M5	3	3.1	40.91
		7	3.95	41.07
		28	5.1	47.83
		56	5.4	44

3.3 Flexural Strength

A servo controlled universal testing machine with displacement control of the crosshead was used. The view of the flexural test set up and the loading of the test specimen is shown in Figures 4 and 5 respectively. The bearing surfaces of the supporting and loading rollers are wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers. The specimen is then placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould, along two lines spaced 133 mm apart for 400mm span. The axis of the specimen is carefully aligned with the axis of the loading device. No packing is used between the bearing surfaces of the specimen and the rollers. The load is applied without shock and increasing continuously at a rate such that the extreme fibre stress increases at approximately 1800 N/min. The beams were simply supported hinge on one side and roller at the other end. The supports were horizontally movable to avoid any restraint on the deformation until the specimen completely ruptures. The load is increased until the specimen fails, and the maximum load applied to the specimen during the test is recorded. Table 5 gives the flexural strength of beams for various mixes at 3, 7, 28 and 56 days respectively. The bar chart showing the increase in flexural strength for various mixes is shown in Figure 6. Concrete mixes revealed an increase of upto 32.14% in flexural strength as a result of replacement of manufactured sand up to 100% as seen in Table 5 compared to controlled concrete at the end of 28 days. Concrete with manufactured sand gives better surface finish. It has been observed that the

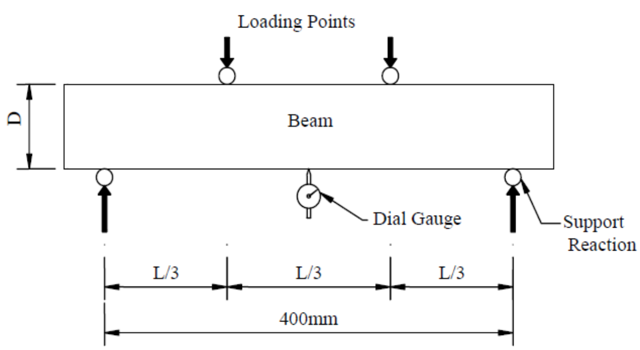

Figure 4. Schematic view of the flexural test setup.

Figure 5. Loading of the specimen.

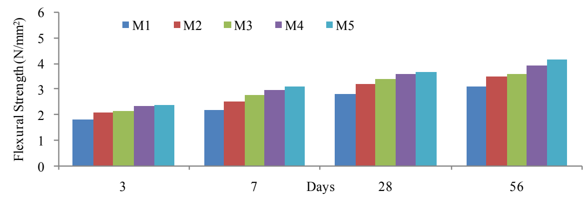

Figure 6. Variation in flexural strength of concrete.

compressive, split tensile and flexural strength of concrete with replacement of natural sand by manufactured sand goes on increasing upto full replacement. This may be due to the replacement of natural sand by manufactured sand shows the optimum reaction with optimum filler capacity.

Table 5. Flexural strength results of concrete

S.No	Mix Designation	Days	Flexural Strength (MPa)	% increase in Flexural Strength
1.	M1	3	1.8	-
		7	2.2	-
		28	2.8	-
		56	3.1	-
2.	M2	3	2.1	16.67
		7	2.5	13.64
		28	3.2	14.29
		56	3.5	12.9
3.	M3	3	2.15	19.44
		7	2.75	25
		28	3.4	21.43
		56	3.6	16.13
4.	M4	3	2.35	30.56
		7	2.95	34.09
		28	3.6	28.57
		56	3.9	25.81
5.	M5	3	2.4	33.33
		7	3.1	40.91
		28	3.7	32.14
		56	4.15	33.87

4. Conclusions

This study was undertaken with the objective of evaluating the viability of utilizing manufactured sand as a substitute to natural sand in High Performance Concrete. The effect of concrete with partial and full replacement of manufactured sand on the properties of high performance concrete with water cement ratio of 0.41 and the compressive strength, split tensile strength and flexural strength and workability were studied. The effect of partial and full replacement of manufactured sand with natural sand on strength property and workability were evaluated and compared with reference mix.

- The compressive, split tensile and flexural strength of concrete with 100% replacement of natural sand with manufactured sand reveals higher strength as compared to reference Mix (M1).
- An increase of upto 33.87% in flexural strength is seen in Mix 5 as a result of replacement of manufactured sand up to 100% compared to controlled concrete at the end of 56 days.
- The split tensile strength has been increased by 44% when compared to controlled concrete at the end of 56 days as a result of replacement of manufactured sand up to 100%
- The compressive strength results showed that an increase in 23.73% in Mix 5 at the end of 56 days as a result of replacement of manufactured sand up to 100%

Thus, it can be seen that manufactured sand can be a viable substitute for natural sand to produce HPC.

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