Experimental investigation on high performance RC column with manufactured sand and silica fume

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Experimental investigation on high performance RC column with manufactured sand and silica fume

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Abstract. In recent years, the use High Performance Concrete (HPC) has increased in construction industry. The ingredients of HPC depend on the availability and characteristics of suitable alternative materials. Those alternative materials are silica fume and manufactured sand, a by products from ferro silicon and quarry industries respectively. HPC made with silica fume as partial replacement of cement and manufactured sand as replacement of natural sand is considered as sustainable high performance concrete. In this present study the concrete was designed to get target strength of 60 MPa as per guide lines given by ACI 211- 4R (2008). The laboratory study was carried out experimentally to analyse the axial behavior of reinforced cement HPC column of size 100x100x1000mm and square in cross section. 10% of silica fume was preferred over ordinary portland cement. The natural sand was replaced by 0, 20, 40, 60, 80 and 100% with Manufactured Sand (M-Sand). In this investigation, totally 6 column specimens were cast for mixes M1 to M6 and were tested in 1000kN loading frame at 28 days. From this, Load-Mid height deflection curves were drawn and compared. Maximum ultimate load carrying capacity and the least deflection is obtained for the mix prepared by partial replacement of cement with 10% silica fume & natural sand by 100% M-Sand. The fine, amorphous and pozzalonic nature of silica fume and fine mineral particles in M- Sand increased the stiffness of HPC column. The test results revealed that HPC can be produced by using M-Sand with silica fume.

1. Introduction

Globally many countries are growing rapidly in the construction industry which uses natural resources for the development of the infrastructure such as highways, hydraulic and industrial projects, hydroelectric power projects etc. The improved performance of concrete plays the role to meet the requirements of industrialization the need for high performance concrete is vital. The mechanical and durability properties of HPC is mainly affected by the use of these mineral admixtures mainly due to their filler effect and Pozzolonic reaction[1 ,2]. A by - product obtained from the production of silicon and ferrosilicon alloys is silica fume which has high SiO_2 content. Silica fume has an amorphous state and extreme fineness as compared to other supplementary cementitious materials which improves mechanical and durability properties [3, 4]. Researchers found that 5-15% replacement of cement by silica fume with a smaller dosage of super plasticizer makes the concrete workable and also improves strength of concrete [5,6]. The natural sand has extracted continuously from river beds leads to many environmental problems such as disruption to aquatic life, lowering of the underground water table which affects agriculture, sliding of river bank etc. In order to balance this situation many alternative materials have been identified as a substitute for river sand [7,8]. M-Sand is a crushed aggregate produced from hard stone which is rough, angular shape, washed and properly graded is used as a substitute for river sand. The mechanical and durability properties of concrete are improved due to its filler and interlocking effect between the particles of M-Sand. [9-11].Taking into consideration of the above mentioned points, this research work poses to use the manufactured sand as a replacement of natural sand in varying percentages (0%, 20%, 40%, 60%, 80% and 100%) which would be efficient in conserving the natural resources if adopted in the construction sector throughout the country and world. The 10% of silica fume was partially replaced with cement. Glenium B233 super plasticizer was added to 1.5% by weight of binder (cement & silica fume).

2. Materials

2.1 Cement

Portland cement 53 grade of specific gravity 3.15 were used. Table 1 illustrated the physical and chemical properties of cement.

2.2 Silica fume

Commercially available silica fume was named Elkem – Micro silica 920 D in dry densified form conforming the requirements of ASTM C1240[12] was used. Table 1 illustrated the properties of cement and silica fume.

Table 1. Properties of Cement & Silica fume

Properties	**Cement**	**Silica fume**
Physical Properties		
Surface area, m^2/kg	320	20,000
Specific gravity	3.15	2.2
Size, micron	-	0.1
Bulk density, kg/m	-	576
Initial setting Time in minutes	45	-
Final setting Time in minutes	375	-
Chemical Properties, Percentage		
SiO_2	90-96	20-25
Al_2O_3	0.5-0.8	4-8
MgO	0.5-1.5	0.1-3
Fe_2O_3	0.2-0.8	0.5-0.6
CaO	0.1-0.5	60-65
Na_2O	0.2-0.7	0.1-0.5
K_2O	0.4-1	0.4-1.3
Loss of Ignition	0.7-2.5	0.1-7.5

2.3 Natural Sand

Locally available river sand was used and the specific gravity is 2.65. The bulk density is and Fineness modulus of river sand is 1726 kg/m^3 and 2.69 respectively.

2.4 Manufactured Sand

Manufactured Sand was collected from I Blue Minerals Pvt. Ltd. Karur, India and the bulk density is 1748 kg/m^3. It has specific gravity and fineness modulus of 2.65 and 2.86 respectively. The test results from sieve analysis are presented in Table.2.

Table 2. Percentage of passing for Natural Sand and M-Sand

Sieve Size	Natural sand Percentage of Passing	M-Sand Percentage of Passing	IS 383 Grading limits for Zone II
4.75mm	97	99.2	90-100
2.36mm	92.2	93.6	75-100
1.18mm	77	56.6	55-90
600µm	52.2	38.6	35-59
300 µm	10.6	18.4	8-30
150 µm	2	7.4	0-10
	Both the sands falls on Zone II of IS 383[13]		-

2.5 Coarse Aggregate

Coarse aggregate confirming to Indian standard 383 (1970) was used and it satisfied its requirement. Aggregate passing through 12.5 mm sieve, 10 mm sieve and 4.75 mm sieve was 90–100%, 40–80% and 0–10% respectively. The specific gravity of coarse aggregate is 2.71.

2.6 Super plasticizer

Glenium B233 was used as chemical admixture, poly-carboxylic ether based to improve the workability of concrete. The specific gravity of the superplasticizer is 1.09 .

2.7 Water

Fresh portable water, was used for mixing the concrete as it is free from acid and organic substance.

3. Methods

3.1 Mix design and sample preparation

High Performance concrete was designed based on the guidelines given in ACI 211- 4R (2008) "Guide for selecting proportions for high strength concrete with portland cement and other cementations materials"[14] to get a compressive strength of 60N/mm^2 at the age of 28 days. Concrete mixtures (M1, M2, M3, M4, M5 and M6) were made by replacement of N-Sand with M-Sand in replacement percentages of 0,20, 40, 60, 80 and 100 and the cement was replaced by 10% of silica fume. Mix proportion 1:1.1:1.58:0.32 (Cement : Sand : Aggregate: Water binder Ratio) was arrived in this investigation. The details of column reinforcement are presented in Figure 1.

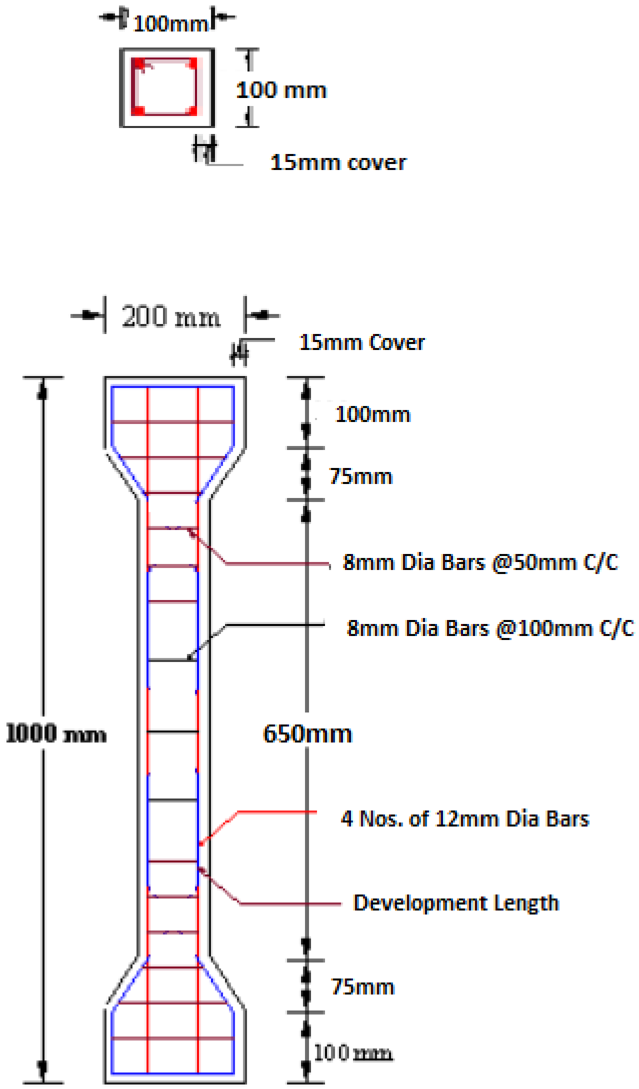

Figure 1. Reinforcement Details of the column

Columns were cast using wooden moulds as per Figure 1. The concrete specimens cube and beams were cast using standard steel moulds. Cube of 100mm size of three numbers for compressive strength and beam of 100mm x 100mm x 500mm size three numbers for flexural strength were cast for each mix. The quantities of cement, fine aggregate, coarse aggregate, silica fume, M-Sand was measured and homogeneous mixing of the above is achieved by means of pan mixer. The W/B (Cement & Silica fume) was kept constant as 0.32 . The dosage of super plasticizer was used at 1.5% by weight of binder to get the workability of concrete. The concrete was compacted by needle vibrator. The specimens were de moulded after 24 hours from the moulds and were being cured with water for 28 days.

3.2 Testing of Specimens

Compressive strength test was done based on IS 1881: Part 116 [15] at the loading rate of 140 kg/cm^2 per minute until the specimens fails. Test was conducted using 2000KN capacity AIMIL Compression Testing Machine. Flexural strength of concrete was carried out using 100KN capacity Flexure Testing Machine of conforming to IS: 516-1959 [16]. The columns ends were supported with rubber pads to get the hinged end condition. The column specimens were brought into the centre line of the axial load and was ensured that the load was applied axially with permissible eccentricity throughout the test . All the columns were tested for compression in a loading frame of capacity of 1000 kN. To measure the lateral deflection of the column LVDT were placed at mid-section of the column.

4. Results and Discussion

4.1 Compressive Strength and Flexural Strength

Table.3. gives the variation of compressive strength and flexural strength at the age of 28 days.

Table 3 Compressive and Flexural strength results of HPC

Mix Details	Compressive Strength in N/mm^2	Flexural strength in N/mm^2
M1	73.85	7.12
M2	74.22	7.43
M3	76.55	7.92
M4	77.43	8.21
M5	78.55	8.46
M6	80.11	9.24

From the results we can conclude that, concrete mixture made with 100% manufactured sand and 10% silica fume shows higher compressive strength than mix M1. Also it was noticed that, compared to the mix M1 the 28 days compressive strength increased by 1%, 4%, 5% 7% and 9.5% for the mixes M-2, M-3, M-4, M-5 and M-6 respectively. Due to high SiO_2 of the silica fume and better particle size of manufactured sand results higher strength. Flexure strength of concrete has observed the same pattern as compressive strength. The above results are supported by previous studies about the influence of manufactured sand as fine aggregate on the normal strength concrete [17-19].

4.2 Structural behavior of column

Comparison of load verses mid span deflection curves was presented in Figure 2.

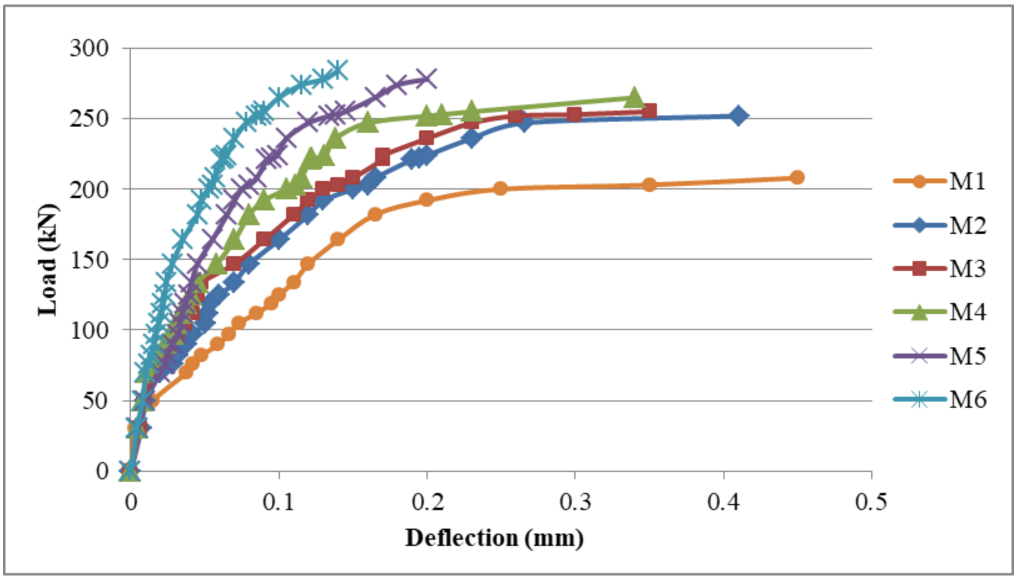

Figure 2. Comparison of load and mid span deflection of columns

a) Test setup b) Crack pattern for mix M6

Figure 3. Test setup & Crack pattern

Table 4. Load and deflection results of HPC columns

Mix ID	First crack load (kN)	Ultimate load (kN)	Deflection (mm)
M1	170	208	0.54
M2	172	210	0.6
M3	185	222	0.48
M4	187	252	0.41
M5	192	255	0.35
M6	216	265	0.34

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From Table 4, it can be noted that the deflection is increasing linearly with the load. It is noticed that for control concrete mix M1, the first crack appears at a load of 170 kN and it does not appear for the optimum concrete mix M6 until 216kN. For the mix M1, the ultimate load carrying capacity of was 208 kN and for mixes with 10% silica fume, the ultimate load capacities were found to be 210kN, 222kN, 252kN , 255kN and 265 respectively for 20, 40, 60 and 100% of M-Sand. The capacities of mixes M2, M3, M4 and M5 increased about 1, 6, 21,23 and 27% respectively when compared to the M1 HPC mix. From the above observations, it is seen that the combination of 100% M-Sand and 10% silica fume replaced by fine aggregate and cement respectively. The load carrying capacity is found to be very high compared to M1 (about 20%) and the corresponding deflections are found to be lesser.

5. Conclusion

Based on the investigations, following conclusions can be made

- By gradually increasing the percentage of M-Sand from 0 to 100% with 10% of silica fume the compressive strength and flexural strength of concrete increases.
- The optimum percentage of 100% M-Sand replaces natural sand in presence of cement by 10% of silica fume for achieving maximum compressive and flexural strength.
- The RC columns with M-Sand sustained more load under axial loading, and developed smaller deflections than the column with river sand.
- The load carrying capacity is found to be 27% higher for the concrete made with 100% M-Sand and 10% silica fume is replaced with cement by comparing to column with natural sand.
- Based on the test results, High Performance Concrete with silica fume and complete replacement of natural sand by M-Sand can be used in the construction industry to minimize the environmental pollution.

References

[1] Malhotra V M and Mehta P K 1996 *Pozzolanic and Cementitious Materials (Advances in concrete technology)*, Gordon and Breach Publishers, Philadelphia, United States, **1**.

[2] Brooks J J, Megat Johari M A and Mazloom M 2000 Effect of admixtures on setting times of high strength concrete *Cement Concrete Composites*, **22** 293–301.

[3] Mahasenan 2003 *The Cement Industry and Global Climate Change: Current and Potential Future Cement Industry CO_2 Emissions, Greenhouse Gas Control Technologies – 6th International Conference*, Oxford: Pergamon, 995–1000.

[4] Megat Johari M A, Brooks J J, Shahid Kabir and Patrice Rivard 2011 Influence of supplementary cementitious materials on engineering properties of high strength concrete *Construction and Building Materials*, **25** 2639–2648.

[5] Duval R and Kadri K H 1998 Influence of Silica fume on the workability and the Compressive strength of High performance *Concrete Cement and Concrete Research*, **28(4)** 533-547.

[6] Cong X, Gong S, Darwin D and McCabe S L 1992 Role of Silica Fume in compressive strength of cement Paste Mortar and Concrete *ACI Materials Journal*, **89(4)** 375-387.

[7] Lohani T K , Padhi M, Dash K P and Jena S 2012 Optimum utilization of quarry dust as partial replacement of sand in concrete *Int. Journal of Applied Sciences and Engineering Research*, **1** 391-404.

IOP Conf. Series: Materials Science and Engineering **263** (2017) 032021 doi:10.1088/1757-899X/263/3/032021

[8] Meenakshi Sudarvizhi and Ilangovan 2011 Performance of copper slag and ferrous slag as partial replacement of sand in concrete *International Journal of Civil & Structural Engineering*, **1** 918-27.

[9] Syam Prakash V 2007 *Ready mixed concrete using manufactured sand as fine aggregate 32nd Conference on Our World in Concrete & Structures*, Singapore, 28-29.

[10] Elavenil S and Vijaya B 2013 Manufactured Sand, A Solution and an Alternative to River Sand and in Concrete Manufacturing, *Journal of Engineering, Computers & Applied Sciences*, **2(2)** 20-24.

[11] Hudson B P 1997 Manufactured Sand for Concrete, *The Indian Concrete Journal*, **71(5)** 237-240.

[12] ASTM C1240 1993 *Standard Specification for Silica fume used in Cementitious Mixtures*. ASTM International

[13] IS 383- 1970 2002 *Indian standards specification for coarse and fine aggregate from natural source for concrete*.

[14] ACI 211.4R 2008 *Guide for selecting proportions for high strength concrete using Portland cement and other cementitious materials*, ACI Committee 211, Farming-ton Hills, Michigan.

[15] IS: 516 1959 *Indian Standard methods of test for strength of concrete, Bureau of Indian Standards*, New Delhi, India.

[16] IS: 5816 1999 *Method of test for splitting tensile strength of Concrete*, Bureau of Indian Standards, New Delhi, India.

[17] Ahmed E. Ahmed 1989 Properties of concrete incorporating Natural and Crushed Stone very fine Sand *ACI Material Journal* **86(4)** 417-424.

[18] Sahu A K , Sunil K and Sachan A K 2003 Crushed stone waste as fine aggregate for concrete *The Indian Concrete Journal* 845-847.

[19] Prakash Rao and Giridhar Kumar 2004 Investigations on concrete with stone crusher dust as fine aggregate *Indian Concrete Journal*, 45 – 50.