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An experimental study on the properties of SCC with manufactured sand

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The findings of a study on Self Compacting Concrete (SCC), made using natural and manufactured sand (M-sand) are presented. The referral SCC (M25) was made by substituting a part (20%) of Ordinary Portland Cement (OPC) with Class-F Fly Ash (FA). The other SCCs were made by replacing parts of natural sand (NS) with M-sand, by mass. The workability parameters of SCCs in fresh state were determined as per the recommendations EFNARC-2005. The specimen of both SCCs were cast and tested for important strength parameters at different ages as per Indian standards. It is found that 50% of NS can be replaced by M-sand. The specimen's water absorption was also studied up to 90 days.

Keywords: Ordinary Portland Cement, SCC, workability, M-sand, FA.

Introduction

The use of SCC is increasing and gaining popularity the world over. It's composition is different than the normal concrete mixes and it utilizes a lot of fines which consists of sand and other pozzolanic materials. In view of the increasing natural and global consensus on the environmental protection, the governments have put restrictions on mining of natural sand from river beds. The M-sand may supplement/ fulfil the shortage of natural sand.

Ramanathan *et al.*[1] stated that the properties of SCC made by replacing 30% of OPC with FA. It is also stated that the loss of compressive strength (CS) and water absorption are decrease with increase in FA content. Gaywala *et al.*[2] stated that SCC's compressive, split-tensile, flexural and pull out strengths were maximum at 15% replacement level of OPC with FA. Water absorption increases with FA content although it decreases with an increase in the curing period[3]. FA is considered to be the most appropriate pozzolana for sustainable SCC production[4]. 50–60% FA can be included in SCC to improve workability parameters with a substantial increase in CS is observed upto 180 days[5]. The addition of pozzolanas have positive effect on the properties of SCC compared to Normally Vibrated Concrete (NVC)[6]. The FA exhibits ball bearing effect due to which the dose of plasticizer is decreased and self-compactability is substantially improved[7]. The addition of FA in SCC forms additional C-S-H gel in long term, specially after 56 days, and results in an increase in CS[8]. SCC incorporating mineral admixtures reduces water absorption due to improved pore structure[9]. M-sand has been used successfully as a filler material for preparing SCC. Its use improves the hardened properties and reduces the environmental impact also[10]. The CS of SCC containing mineral admixtures is more than the normal SCC[11,12]. For the same paste composition, the CS of M-sand mixed concrete is more than that containing natural sand only[13]. The use of M-sand containing no more than 13% stone powder content has been reported to be advantageous for the long-term split-tensile strength (STS) of M-sand concrete[14].

This work compares different SCCs with and without M-sand. The SCC was prepared using supplementary cementations material FA. For partial substitution of the fine aggregate, M-sand was used. For preparing the SCCs, 20% of OPC was substituted by FA on equal weight basis, and fine aggregate was replaced by M-sand on equal weight basis (10, 20, 30, 40, 50 and 60%). The cubes (size - 100 mm), cylinders (size - 100 mm×200 mm) and beams (size - 100 mm×100 mm×500 mm) were cast for CS, STS and flexural strength (FS), respectively. The cast specimen were tap-water cured and tested at 7, 28, 56 and 90 days. The weights of the samples were measured at different time intervals for determining the water absorption.

Experimental

Raw materials and their properties:

For development of this research, a 43 grade OPC (Brand: MP Birla), confirming to IS: 8112-1989, was used. Rounded NS falling in Zone-II of IS: 383-1970 was used. The other important properties of the NS are: specific gravity - 2.65; fineness modulus - 2.7; bulk density - 1680 kg/m^3. The bulk density; specific gravity and fineness modulus of M-sand are 1744 kg/m^3, 2.72 and 3.08, respectively. M-sand was procured from Jhansi, UP, and it also satisfied the requirements of Zone-II. The properties of 10 and 20 mm coarse aggregates are given in order: specific gravity - 2.66 and 2.7; water absorption - 1.0 and 0.9%; fineness modulus - 6.7 and 7.2; bulk density - 1590 and 1560 kg/m^3. The above values satisfy the requirements of IS: 383-1970. The FA (class - F; colour - grey; specific gravity - 2.13), satisfying the requirements of IS: 3812-2000, was purchased from NTPC-Unchahar (UP). A Master Rheobuild 817RL superplasticizer based on polycarboxylic ether with a density of approx. 1.08 was used. The distribution of the particle size of both the NS and M-sand is presented in Fig. 1. Table 1 presents the constituents of both OPC and FA.

M25 grade SCC mix was prepared in this study using 43 grade OPC, satisfying the requirements of EFNARC, 2005. The quantities of different materials in 1 cubic meter of SCC at water/binder ratio - 0.43 was: binder content - 450 kg; sand - 890 kg; coarse aggregate - 750 kg; superplastisizer - 4.95 Kg.

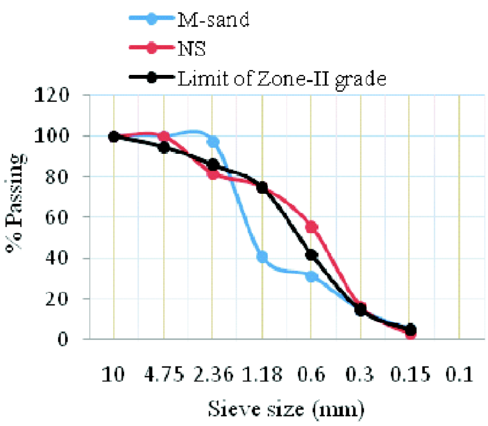

Fig. 1. Distribution of particle size of both NS and M-sand.

Table 1. Constituents of OPC and FA

Chemical composition (%)	OPC	FA
Silicon dioxide (SiO_2)	20.05	55.40
Aluminum oxide (Al_2O_3)	61.95	4.19
Iron oxide (Fe_2O_3)	4.12	6.82
Magnesium oxide (MgO)	2.77	2.02
Potassium oxide (K_2O)	0.94	1.93
Sodium oxide (Na_2O)	0.25	0.62
Loss of ignition	3.11	2.40

A part of OPC (20%) was replaced with FA (by mass) for making all SCC specimens. For determining the optimum dose of M-sand in SCC, NS was replaced at different levels (10–60%, by mass, interval - 10%) with M-sand. Two type of SCC mixes were prepared and are designated as M-1 (SCC without M-sand) and M-2 (SCC with M-sand). The tests performed for determination of the fresh properties are: Slump flow; T50 time; V-funnel; L-box; U-box and J-ring.

Table 2 presents mixture proportions, water/binder ratio and fresh properties. Cubes, cylinders and beams of both M-1 and M-2 type SCC were cast to assess their strengths in compression, tension and flexure. The water cured specimen were tested at 7, 28, 56 and 90 days. The cubical and cylindrical specimen were tested following the specifications of IS: 516-1959 and IS: 5816-1999, respectively. The FS was determined using a two point method as per requirements of IS: 516-1959.

Table 2 Mixture composition of SCCs

Mix properties	M-1 type	M-2 type
w/b ratio	0.44	0.44
OPC (kg/m^3)	360	360
Fly ash (kg/m^3)	90	90
Coarse aggregate (kg/m^3)	750	750
Fine aggregate (kg/m^3)	890	445
M-sand (kg/m^3)	–	445
Water (kg/m^3)	190	190
Superplastisizer (kg/m^3)	4.95	4.95

Optimization of M-sand:

After 7 and 28 days of tap-water curing, the CS of all the cubes were determined to find the optimum M-sand level, and the results are presented in Table 3. The optimum dose of M-sand was found to be 50% (by mass), with respect to CS.

Table 3. CS of specimens at various M-sand levels

Replacement level (%)		CS (MPa)	
M-1 type	M-sand	7 days	28 days
20% FA	0	25.00	32.33
20% FA	10	26.67	33.00
20% FA	20	27.33	34.67
20% FA	30	28.67	35.00
20% FA	40	29.33	36.67
20% FA	50	30.67	38.33
20% FA	60	29.00	35.33

Results and discussion

Workability parameters of SCC:

The values of all the workability parameters for both the mixes i.e. M-1 and M-2 type are given in Table 4. Further, these values are shown in Figs. 2–4 for different mixes with varying percentages of M-sand. Table 4 indicates that the fresh properties of M-2 mixes are influenced by the replacement of the NS with M-sand, but the test results are within the EFNARC limits.

Table 4. Test parameters of fresh concrete for both mix types

Tests	M-1 type	M-2 type
Slump-flow (mm)	720	695
T_{50} time (s)	3	4.2
V-funnel (s)	10	11.2
L-box (h_2/h_1)	0.96	0.87
U-box (mm)	17	22
J-ring (mm)	6	8

Hardened properties of SCC

Compressive strength (CS):

Fig. 5 shows the variation of CS for both M-1 and M-2 type mixes. The CS of type M-1 SCC at 7 days is around

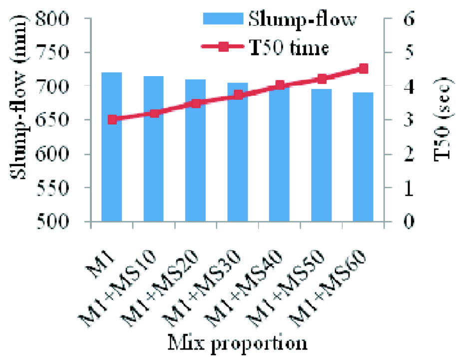

Fig. 2. Variation of slump-flow and T_{50} time of different mixes.

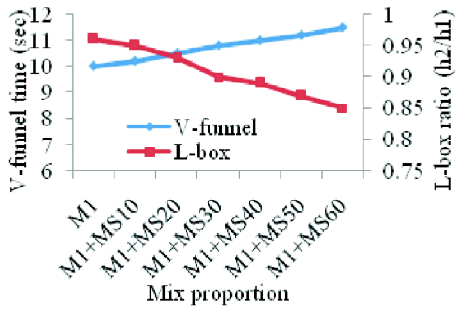

Fig. 3. Variation of V-funnel time and L-box ratio of different mixes.

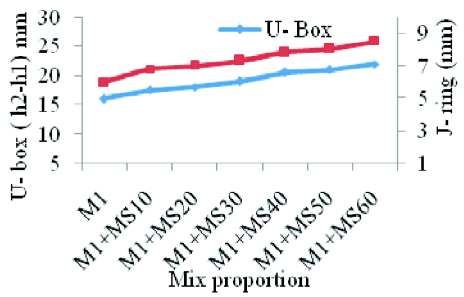

Fig. 4. Variation of U-box and J-ring values of different mixes.

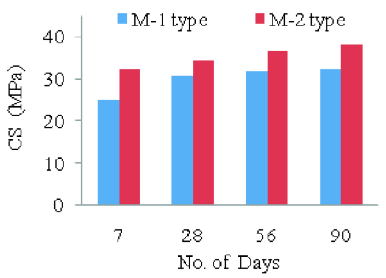

Fig. 5. CS of the specimens.

25.0% lower than that of M-2. The CS of M-2 mix was found to be 11.93, 15.78 and 17.53 % higher at 28, 56 and 90 days, respectively. With age, the difference in the CS of the two mixtures is found to increase. This increment may be due to M-sand mixed concrete's optimized pore structure.

Split-tensile strength (STS):

The variation of STS for both mixes (M-1 and M-2 type) is shown in Fig. 6. The M-1 type SCC has about 11.0% lower STS at 7 days compare to the M-2 type. The STS of the M-2 type is found to be 24.67, 16.60 and 13.58% higher at 28, 56 and 90 days, respectively.

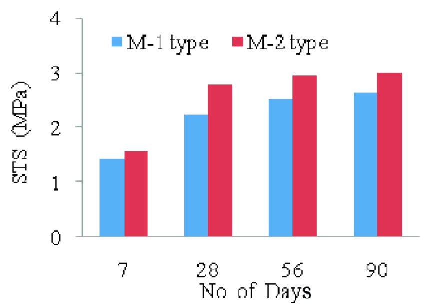

Fig. 6. STS of the specimens.

Flexural strength (FS):

The results of the FS test is performed on different mixes (M-1 and M-2 type) are shown in Fig. 7. The M-1 type has about 8.50% lower flexural than the M-2 type at 7 days. At 28, 56 and 90 days also, it is found to be higher for M-2 type by 8.29, 6.76 and 5.87%, respectively.

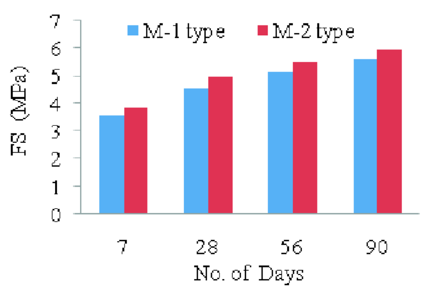

Fig. 7. FS of the specimens.

Water absorption:

For both M-1 and M-2 type mixes, the water absorption values are included in Fig. 8. It's obvious from Fig. 8 that M-2 type's water absorption is lower than that of the M-1 type. Besides that, it is reported that both NVC and SCC show a lower water absorption with a rise in age[15]. The FA and M-sand act as a filler material and help in reduction of water absorption. M-2 type's water absorption is found to be 17.53, 13.72, 11.94 and 9.71% lower than the M-1 type at 7, 28, 56 and 90 days, respectively. Other researchers have also reported the same pattern[3].

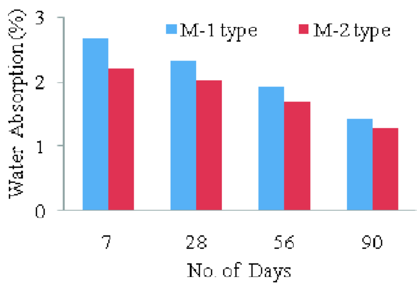

Fig. 8. Water absorption of specimens.

Conclusions

The following are concluded from the detailed investigation.

(i) The workability and/or flowability of SCC mix decrease slightly as M-sand content increases; however, these are within the EFNARC limits.

(ii) The optimum dose of M-sand in SCC is 50% with respect to compressive strength.

(iii) All the strength parameters improve significantly on addition of M-sand at optimum level.

(iv) The water absorption and pore spaces in SCC decrease significantly on inclusion of M-sand.

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