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Effect of Fineness Modulus of Manufactured Sand on Durability Characterstics of Self Compacting Concrete

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Abstract

Self compacting concrete (SCC) is defined as a flowable concrete highly applicable fr congested reinforced structural elements and high durablity. SCC requires high finer particles to attain liquid flow without any external pressure application. Natural river sand consumption is highly increasing due to rapid growth of construction industry and creating several environmental issues and as alternate to natural sand manufactured sand (MSand) is being used as fine aggregate. This research is mainly concentrated on gradation of fine aggregate to get required durability by examine the effect of different fineness modulus (FM) of MSand (2.5, 2.7 and 2.9) on the durability characterstics of SCC with blending of binding materials as SCC_25FA_10SF; SCC_25FA_10SF and SCC_25FA_5SF_5MK. The test methods adopted to evaluate the durability charcters are water absorption and rapid chloride permeability test after curing periods of 28, 56 and 112 days. Results showed that the durability charcterstic values of SCC with FM value of 2.7 aquired better results than other FM values. Hence, it is concluded that proper gradation of finer and coarser fractions of MSand has to be maintained to attain desired durability charcterstics in SCC at hardened state.

Keywords:

Self compacting concrete;
Manufactured sand;
Fineness modulus;
Mechnical properties;

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1. Introduction

Self compacting concrete (SCC) can be called as a fluid concrete as it doesn`t requires any external forces to fill the formwork easily designed for heavily congested reinforcement under its own weight [1]. In SCC, the aggregates contribute major share approxiametly 60–70% of the total quantity. Proper choice of aggregates plays a crucial role on the fresh & durability properties of concrete [2]. Aggregate physical characteristics and grading highly influences the flowable charcters like workability, pumpability, bleeding and segregation of fresh concrete in wet stage and durability charcter at hardened stage [5]. The effects of shape and texture of fine aggregate are much more important than the effects of coarse aggregate [4]. In general, the demand of natural river sand is quite high in developing countries to satisfy the rapid infrastructure growth, in this situation developing country like India is facing severe shortage in attaining good quality of natural river sand [5]. For the most part in India, river sand deposits are being washed-out and causing serious threat to environment in shape of ground water, land sliding etc.

As the over consumption of river natural sand led to numerous environmental issues thereby government imposing a ban on the unrestricted use of natural river sand. This has resulted in the shortage and become uneconomical. Hence, an alternative to river sand has become the need of the hour. Several alternatives materials viz. foundary sand, fly ash, limestone powder have already been used as a fractional replacement of natural river sand in concrete mixes. However, shortage in required quality is the major limitation in some of the above materials. Now a day's, sustainable infrastructural growth demands the alternative material that should satisfy technical prerequisites of fine aggregate as well as it should be available in large quantities. The promotional use of manufactured sand (MSand), which is purpose made fine aggregate produced by crushing and screening, will conserve the natural resources for the sustainable expansion of the concrete in construction industry. By using appropriate impact crushing machinery, it is possible to produce cubical particle shapes with uniform grading, consistently under controlled conditions [6]. Manufactured sands contain high fines content [7,9]. Generally, the fines are composed of rock dust rather than the silts and clays in the case of natural sands. Due to the presence of high fines content, the Msand has a significant influence on the water demand and the workability of the mortar [8, 5].

Properties of concrete can be enhanced and reduction in green house gas (GHG) emissions can be attianed by substituting OPC with flyash , which is a secondary product obtained from thermal power stations [13]. Fly Ash is used as a pozzolana in concrete and can easily used as 15–35 percent substitute for cement in concrete mixes without reduction of strength [14, 15]. Further, fine particles present in M-sand and fly ash with their spherical shape as well as glassy nature, behaves like ball bearing which improves the packing of the concrete and thereby results in reduction of voids [16]. A number of researches have been done on properties of CSC so far. It has been established that qualified concrete with satisfactory strength and durability can successfully be prepared using CS [5].

The resistance to chloride penetration of concrete is significantly increased with the incorporation of finer fly ash particles [24] Such an increase in chloride-ion penetration results from the reduced water-to-binder ratio, the reduced average pore-size of the paste and the improved interfacial zone. The incorporation of fly ash may also enhance the workability of the mixes due to the smooth spherical surfaces of the fine fly ash particles. Hence the use of higher volumes of fly ash in concrete is advantageous in reducing the permeability of concrete due to their filler as well as pozzolanic effects [14]. In the present study, an attempt is made to investigate the chloride permeability resistance characteristics of a few candidate selfcompacting, high-volume fly ash concrete mixes. Further, effect of blending other mineral admixtures like GGBFS silics fume, metakaolin and rice husk ash concrete mixes are also examined.

It is pointed out that manufactured sand is anytime better than river sand. The particle shape is cubical, which is almost closer to rounded river sand. Another issue associated with river sand is that of obtaining required grading with a fineness modulus (FM) of 2.4 to 3.1. Generally FM of 2.2 to 2.6, 2.6 to 2.9 and 2.9 to 3.2 indicates that the sand is fine, medium and coarse confirming to grading zones ranging from IV to I (IS383). It has been verified and found, at various locations across south India, that it has become increasingly difficult to get river sand of consistent quality in terms of grading requirements and limited silt / clay content. In case of manufactured sand with well-designed screening system the required grading and fineness modulus (2.4 to 3.1) can be achieved consistently. It must be noted that properly graded aggregates can improve both fresh, hardened and durability properties of concrete. Owing to the importance of grading of fine aggregates, this investigation is carried out to evaluate the SCC fresh & durability properties using MSand with different values of fineness modulus.

2. Research Method

Our objective was to determine the effect of different values of fineness modulus (2.5, 2.7 and 2.9) of MSand on mechanical properties of SCC. The test methods that were conducted to evaluate the properties are water absorption test and rapid chloride permeability test. Water absorption test was conducted on 100mmx100mmx100mm cubes. The difference between the saturated mass and the oven dried mass expressed as a percentage of the oven dried mass gives the saturated water absorption.According to ASTM C1202 test, a watersaturated, 50 mm thick, 100 mm thick diameter concrete specimen is subjected to a 60 v applied DC voltage for 6 hours using the apparatus and the cells are arranged. In one reservoir is a 3.0% NaC1 solution and in the other reservoir is a 0.3 M NaOH solution. The total charge passed is determined and this is used to rate the concrete

2.1 Materials

Ordinary Portland cement 53 grade corresponding to IS 12269:1987 [29], class F fly ash according to ASTM: C 618, silica fume and metakaolin were used in this research. The chemical and physical properties of cement, fly ash, silica fume and metakaolin are presented in Table 1. Crushed granite stones of size 12.5 mm were used as coarse aggregate. The bulk specific gravity in oven dry condition and water absorption of the coarse aggregate were 2.6 and 0.3% respectively. Manufactured sand (MSand) was used as fine aggregate. The bulk specific gravity in oven dry condition and water absorption of MSand were 2.61 and 1% respectively. The gradation of coarse aggregate and fine aggregate were determined by sieve analysis as per IS 383:1970 [30] and presented in the Tables 2 and 3. Polycarboxylate ether based superplasticizer (SP) was used in SCC. The percentage of dry material in SP was 40%.

Table 1: Chemical and physical properties of cementitious material

Particulars	Cement	Class F fly ash	Silica Fume	Metakaolin
Chemical composition				
% Silica(SiO_2)	19.79	**65.6**	**97.20**	**52.5**
% Alumina(Al_2O_3)	5.67	**28.0**	**0.03**	**44.6**
% Iron Oxide(Fe_2O_3)	4.68	**3.0**	**0.04**	**0.9**
% Lime(CaO)	61.81	**1.0**	**0.37**	**0.05**
% Magnesia(MgO)	0.84	**1.0**	**0.28**	**0.16**
% Sulphur Trioxide (SO_3)	2.48	**0.2**	**0.04**	**-**
Physical properties				
Specific gravity	**3.15**	**2.13**	**2.2**	**2.50**
Fineness (m^2/Kg)	**311.5**	**360**	**16000**	**11100**

Table 2: Sieve Analysis of 12.5 mm coarse aggregate

Sieve Size	Cumulative Percent Passing	
	12.5 mm	**IS: 383-1970 Limits**
12.5 mm	99.64	85-100
10 mm	43.36	0-45
4.75 mm	6.67	0-10
2.36 mm	1.4	N/A

Table 3: Sieve Analysis of Msand with different fineness modulus

Sieve Size (mm)	Cumulative Percent Passing				
	FM – 2.3	**FM – 2.5**	**FM – 2.7**	**FM – 2.9**	**FM – 3.1**
4.75	96.00	95.00	93.90	91.96	91.50
2.36	91.50	87.00	84.50	82.43	77.50
1.18	82.00	75.00	70.00	64.86	55.00
0.6	75.00	55.00	50.00	41.87	38.00
0.3	15.00	27.00	20.00	19.81	20.00
0.15	12.00	10.00	10.00	7.85	6.00

2.2 Mix proportions

SCC mixes were prepared with MSand having different fineness of modulus (2.3, 2.5, 2.7, 2.9, 3.1) to evaluate the SCC fresh properties [opt]. As per EFNARC (2002) [31], minimum coarse aggregate content of 28% was maintained for all the mixes. Keeping in view of the savings in cost and various global polluting effects, fresh, mechanical and durability properties of SCC, the replacement level of class F fly ash was kept at 25% as per IS 456:2000 [32] for all mixes and 10% silica fume, 10% metakaolin and 10% (5%silica fuma+5%metakaolin) . Keeping in view of the moderate fines and all SCC properties, water-cementitious ratio (w/cm) by weight was kept at 0.36 for all mixes. SCC mixes have been designated as SCC_FM2.3, SCC_FM2.5, SCC_FM2.7, SCC_FM2.9 and SCC_FM3.1 respectively for various FM values of 2.3, 2.5, 2.7, 2.9 and 3.1. Mix proportions of all SCC mixes (SCC_25FA_10SF; SCC_25FA_10SF and SCC_25FA_5SF_5MK) are remain same and presented in Table 4.

Table 4: SCC mix proportions

Mix	w/cm	Binder kg/m3	Cement kg/m^3	Fly ash kg/m^3	Silica fume kg/m^3	Metakaolin kg/m^3	Water l/m^3	12 mm kg/m^3	Msand kg/m^3	SP l/m^3
SCC_25FA_ 10SF	0.36	496	322.40	124	49.60	-	179	722	863	4.45
SCC_25FA_ 10MK	0.36	496	322.40	124	-	49.60	179	722	863	4.45
SCC_25FA_ 5SF_5MK	0.36	496	322.40	124	24.80	24.80	179	722	863	4.45

2.3 Testing of SCC

As per EFNARC [16], test methods such as slump flow, T_{50cm} Slump flow**,** V-funnel, L-box and U-box were carried out to assess the fresh properties of SCC. Slump flow test is conducted to determine the spread of the SCC. $T_{50\ cm}$ is measured to indicate the viscosity of the SCC. V-Funnel time is measured to indicate the viscosity of the SCC and L-Box, U-Box test is conducted to evaluate the passing ability of SCC. The successful SCC mixes are further used to evaluate the durability charcterstics as in the below mentioned format.

Saturated water absorption test was conducted on 100mmx100mmx100mm cubes at the age of 28, 56 and 112 days. The specimens were weighed before drying in a hot air oven at 1050ºC. The drying process was continued, until the difference in mass between two successive measurements at a 24 hour interval closely agreed. The dried specimens were cooled at room temperature and then immersed in water. The specimens were taken out at regular intervals of time, surface dried and weighed. The difference between the saturated mass and the oven dried mass expressed as a percentage of the oven dried mass gives the saturated water absorption.

The specimens were fit in the chamber with the required brass as well as rubber oaring. The record time is set as 30 minutes and also the log time as 6 hours and 30 minutes and the current of 60V is passed continuously. The data logger records the readings of corresponding cells at the every record time with its initial readings. At the end of log time, the system halts after taking the final reading. Average current flowing through one cell is calculated by,

I = 900 * 2 * I Cummulative coulombs.

3. Results and Analysis

SCC fresh properties i.e., slump flow, $T_{50\ cm}$, V-Funnel time,Lbox ratio (h_2/h_1) and U Box in mm are presented in the Table 5 for all the mixes. Among the following mixes only the succesful mixes i.e.

SCC_FM 2.5, SCC_FM 2.7 and SCC_FM 2.9 are considered for evaluation of hardened properties such as compressive strength and split tensile strength. The strength properties obtained after conducting test by using compression testing machine are presented in the Table 6, compression strength values and Table 7, Split Tensile Strength values for the curing periods of 7, 28 and 90 days.

Table 5: Fresh Properties of SCC mixes

	Mix Type	Slump Flow (mm)	T_{50cm} (sec)	V-funnel Time (sec)	L-box Ratio (h_2/h_1)	U-Box (mm)
SCC_25FA_10SF	SCC_FM2.3	520	7.86	17.22	0.71	33.40
	SCC_FM2.5	610	6.54	12.38	0.81	16.30
	SCC_FM2.7	660	4.04	9.18	0.90	9.80
	SCC_FM2.9	630	6.28	11.26	0.83	11.20
	SCC_FM3.1	525	7.26	15.24	0.75	31.30
SCC_25FA_10MK	SCC_FM2.3	530	6.34	16.32	0.74	32.10
	SCC_FM2.5	620	5.56	10.64	0.84	13.30
	SCC_FM2.7	675	3.56	8.14	0.95	8.40
	SCC_FM2.9	650	4.46	9.18	0.86	10.10
	SCC_FM3.1	540	6.24	14.14	0.78	30.80
SCC_25FA_5SF_5MK	SCC_FM2.3	535	5.46	14.27	0.75	31.60
	SCC_FM2.5	660	4.78	9.28	0.86	11.50
	SCC_FM2.7	695	2.64	6.48	0.98	5.20
	SCC_FM2.9	665	3.82	8.09	0.92	7.40
	SCC_FM3.1	555	5.12	12.38	0.80	30.10
Acceptance criteria as per EFNARC		650-800	3-5	6-12	0.80-1.00	0-30

From the Table 5, it is observed that the mixes with finer & coarser grading value as SCC_FM2.3 & SCC_FM 3.1 for all mixes i.e., SCC_25FA_10SF; SCC_25FA_10SF and SCC_25FA_5SF_5MK can be categorized as a failure mix as the fresh properties of this mixes were not meeting SCC acceptance criteria. It is mainly due to increased finer fraction of MSand at the lower fineness modulus (2.3). This finer fraction of MSand has larger specific area which demands more water and paste. The angular shape of finer particles also increases the plastic viscosity that affect the workability of SCC. SCC_FM3.1 mix also can be categorized as a failure mix mainly due to increased coarser fraction of MSand at the higher FM (3.1). This coarser fraction contains more angular shape and causes increased the yield stress that affect the workability of SCC. From the results, it is clearly observed that from 2.3 to 2.7 FM values, possessing proper gradation of finer and coarser fractions in MSand to obtain adequate SCC fresh properties.

Table 6: water absorption (%) of SCC mixes

Mix Type		Water Absorption(%)		
		28 days	56 days	112 days
SCC_25FA_10SF	SCC_FM2.5	2.84	2.54	2.29
	SCC_FM2.7	2.78	2.47	2.18
	SCC_FM2.9	2.81	2.52	2.23
SCC_25FA_ 10MK	SCC_FM2.5	2.79	2.48	2.21
	SCC_FM2.7	2.72	2.40	2.09
	SCC_FM2.9	2.77	2.43	2.13
SCC_25FA_ 5SF_5MK	SCC_FM2.5	2.73	2.39	2.17
	SCC_FM2.7	2.64	2.31	1.96
	SCC_FM2.9	2.71	2.34	2.13

From the table 6, it is observed that the mixes SCC_25FA_10SF; SCC_25FA_10SF and SCC_25FA_5SF_5MK prepared with MSand of fineness modulus 2.7 given better resistance to water absorption results compared with the other two fineness modulus i.e. SCC_FM2.5 and SCC_FM2.9. Apart from the fineness modulus blending of binding material also influenced the water absorption characteristics marginally among the three mixes i.e. SCC_25FA_10SF; SCC_25FA_10SF and SCC_25FA_5SF_5MK. For all the curing periods 28, 56, 112 days respectively. The above values are depicted in Fig 1, 2 & 3.

Table 7: RCPT Values of SCC mixes

Mix Type		RCPT (Coulombs)		
		28 days	56 days	112 days
SCC_25FA_10SF	SCC_FM2.5	1247	1018	828
	SCC_FM2.7	1238	1011	816
	SCC_FM2.9	1244	1014	819
SCC_25FA_ 10MK	SCC_FM2.5	1239	1008	814
	SCC_FM2.7	1231	1001	806
	SCC_FM2.9	1236	1006	809
SCC_25FA_ 5SF_5MK	SCC_FM2.5	1229	988	808
	SCC_FM2.7	1219	987	791
	SCC_FM2.9	1227	995	803

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From the table 7, it is observed that the mixes SCC_25FA_10SF; SCC_25FA_10SF and SCC_25FA_5SF_5MK prepared with MSand of fineness modulus 2.7 given good resistance to permeability character compared with the other two fineness modulus i.e. SCC_FM2.5 and SCC_FM2.9. Apart from the fineness modulus blending of binding material also influenced the Permeabilty characteristics marginally among the three mixes i.e. SCC_25FA_10SF; SCC_25FA_10SF & SCC_25FA_5SF_5MK. For all the curing periods 7, 28, 90 days respectively. The above values are depicted in Fig 4, 5 & 6.

Water Absorption(%) Vs Fineness Modulus of MSand

RCPT Vs Fineness Modulus of MSand

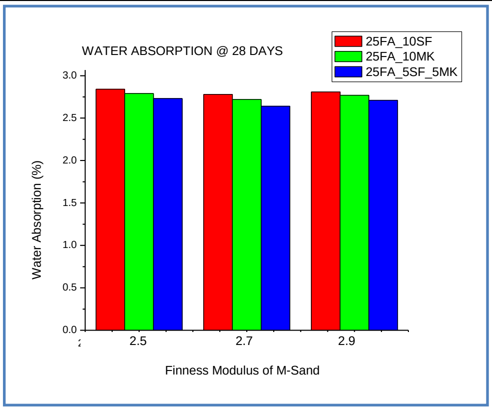

Fig 1. Water Absorption(%)@ 28days

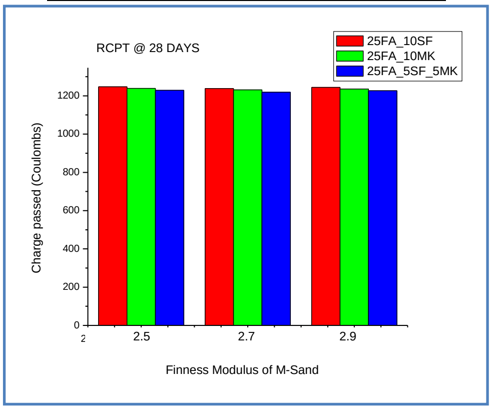

Fig 4. RCPT @ 28 days

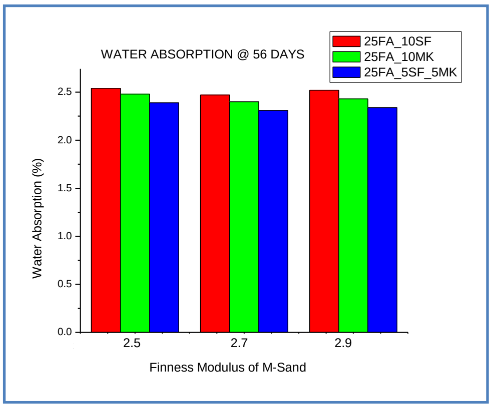

Fig 2. Water Absorption(%)@ 56 days

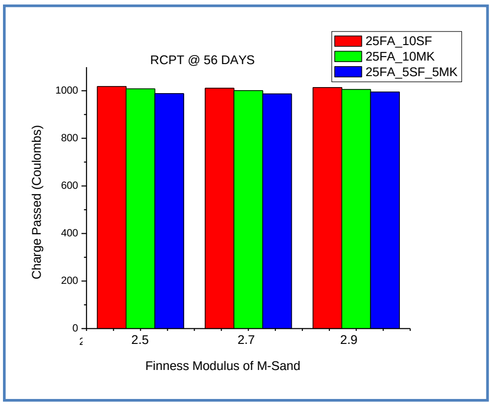

Fig 5. RCPT @ 56 days

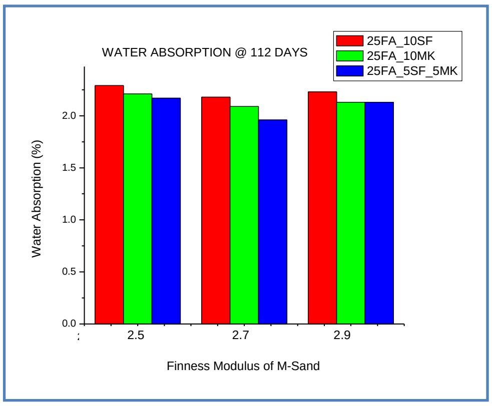

Fig 3. Water Absorption(%)@ 112 days

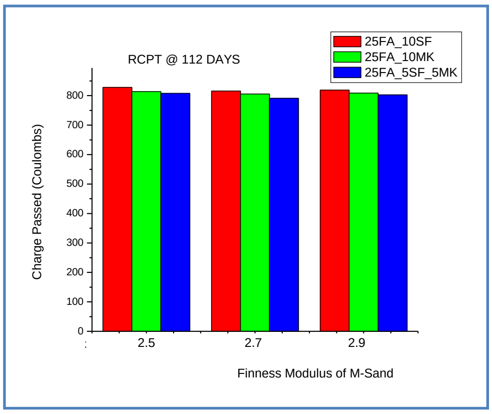

Fig 6. RCPT @ 112 days

4. Conclusions

Based on the results of this experimental investigation, the following conclusions can be drawn:

1. The mix SCC_FM2.3 got failed at fineness modulus of 2.3 as it contains finer fraction which increases the plastic viscosity.
2. The mix SCC_FM3.1 got failed at fineness modulus of 3.1 as it contains coarser fraction which increases the yield stress.
3. Three mixes SCC_FM2.5, SCC_FM2.7 and SCC_FM2.9 are categorized as successful SCC mixes as they met SCC acceptance criteria and used for evaluation of durability charcterstics i.e. water absorption and RCPT.
4. Out of these three successful mixes, the performance of SCC_FM2.7 was observed to be much better than the other two mixes SCC_FM2.5 and SCC_FM2.9 in durability properties.
5. Hence, it is revealed that proper gradation of finer and coarser fractions of MSand has to be maintained to obtain adequate SCC fresh and mechanical properties.

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