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Effect of Manufactured Sand Fineness Modulus on FLEXURAL Properties of SCC

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Abstract—Based on the performance of in all stages of Self compacting concrete (SCC) can be treated as innovative construction material. Consumption of natural river sand deposits causing several environmental issues, as alternate manufactured sand (MSand) are being used as fine aggregate in place of natural river sand. This research is mainly concentrated on gradation of fine aggregate to get required best quality by examine the effect of different fineness modulus (FM) of MSand (2.5, 2.7 and 2.9) on the flexural properties of SCC with blending of binding materials as SCC_25FA_10SF; SCC_25FA_10SF and SCC_25FA_5SF_5MK. The test methods that were conducted are flexural strength for curing periods of 7,28 and 90 days. Results showed that the strength values of SCC with FM value of 2.7 gave better results than other FM values. Hence, it is revealed that proper gradation of finer and coarser fractions of MSand has to be maintained to obtain desired strength in SCC at hardened state.

Keywords: Self compacting concrete, manufactured sand, fineness modulus, flexural strength.

1. INTRODUCTION

Self compacting concrete (SCC) can be called as a fluid concrete as it flows and fills in requried postion without any external forces, mainly for heavily congested reinforcement under its self weight [1]. In SCC, the aggregates contribute nearly 60–70% of the total volume. Proper choice of aggregates plays a crucial role on the fresh properties of concrete [2]. Aggregate characteristics such as shape, texture and grading influence several characterstics during fresh concrete [3]. 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 shortage in getting good quality natural sand [5] . Particularly in India, natural sand deposits are being depleted and causing serious threat to environment as well as the society.

This has led to several environmental issues thereby government imposing a ban on the unrestricted use of natural sand. This has resulted in the scarcity and significant rise in the cost of natural sand. Therefore, an alternative to river sand has become the need of the hour. Some alternatives materials viz. fly ash, limestone powder have already been used as a partial replacement of natural sand in concrete mixes. However, scarcity 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 requisites of fine aggregate as well as it should be available abundantly. 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 development of the concrete in construction industry. By using appropriate impact crushing technology, 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].

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 and hardened properties of concrete. Owing to the importance of grading of fine aggregates, this investigation is carried out to evaluate the SCC fresh properties using MSand with different values of fineness modulus.

2. EXPERIMENTAL STUDY

Our objective was to determine the effect of different values of fineness modulus (2.5, 2.7, 2.9) of MSand on mechanical properties of SCC. The test methods that were conducted to evaluate the properties are compression strength test and split tensile strength test.

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	Metaka olin 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.

3. RESULTS AND DISCUSSION

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 property such as flexural strength. The strength properties obtained after conducting test by using loading frame are presented in the Table 6, flexural 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_10 SF	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: Flexural Strength Properties of SCC mixes

Mix Type		**Flexural Strength (Mpa)**		
		7 days	***28 days***	**90 days**
SCC_25FA_10SF	SCC_FM2.5	4.08	7.29	7.76
	SCC_FM2.7	4.40	7.86	8.37
	SCC_FM2.9	4.25	7.59	8.08
SCC_25FA_ 10MK	SCC_FM2.5	4.86	7.71	8.37
	SCC_FM2.7	5.29	8.39	9.11
	SCC_FM2.9	5.13	8.15	8.84
SCC_25FA_5SF_5MK	SCC_FM2.5	5.20	8.00	8.87
	SCC_FM2.7	5.55	8.54	9.48
	SCC_FM2.9	5.39	8.30	9.21

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 good flexural strength 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 flexural strength characteristics marginally among the three mixes i.e. SCC_25FA_10SF; SCC_25FA_10SF and SCC_25FA_5SF_5MK. For all the curing periods 7, 28, 90 days respectively. The above values are depicted in Fig 1, 2 & 3.

Flexural Strength Vs Fineness Modulus of MSand

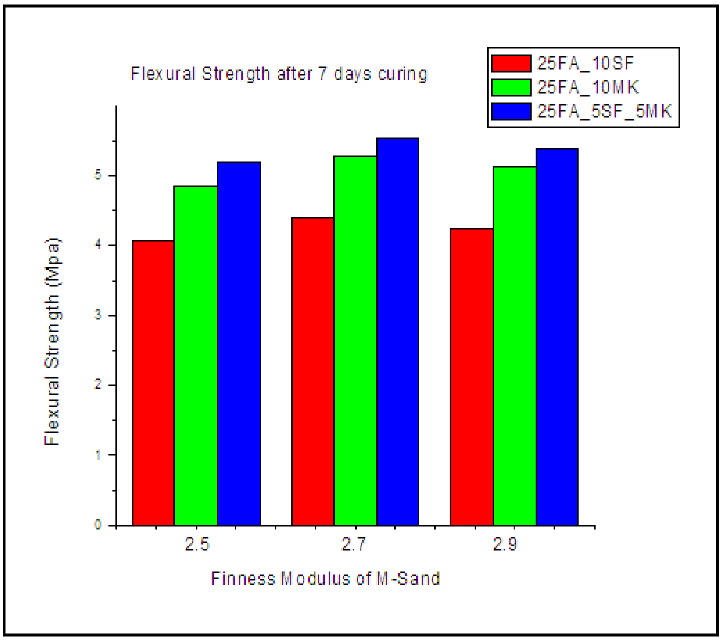

Fig 1. Flexural strength values @ 7days

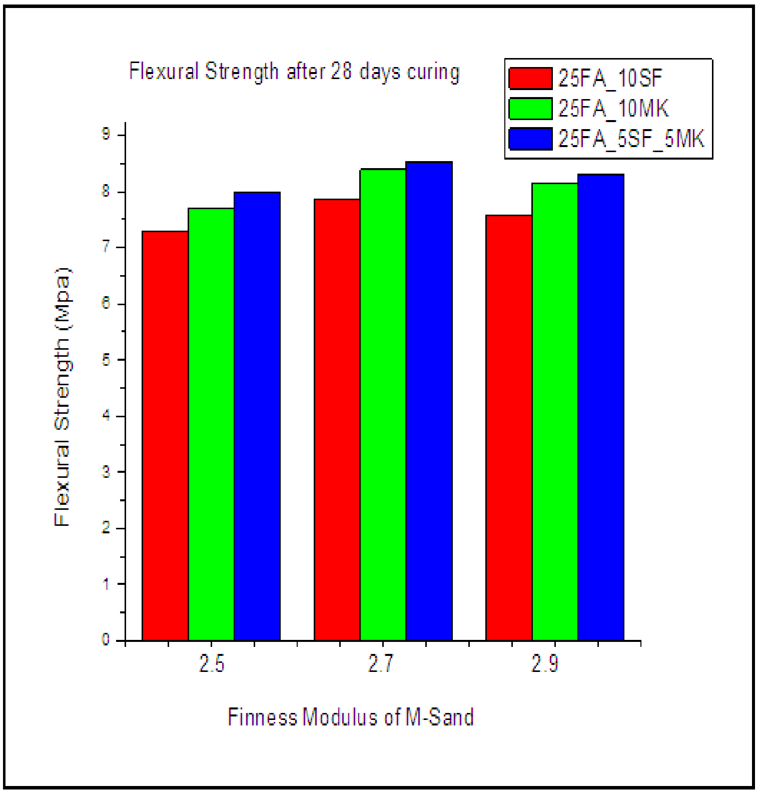

Fig 2. Flexural strength values @ 28 days

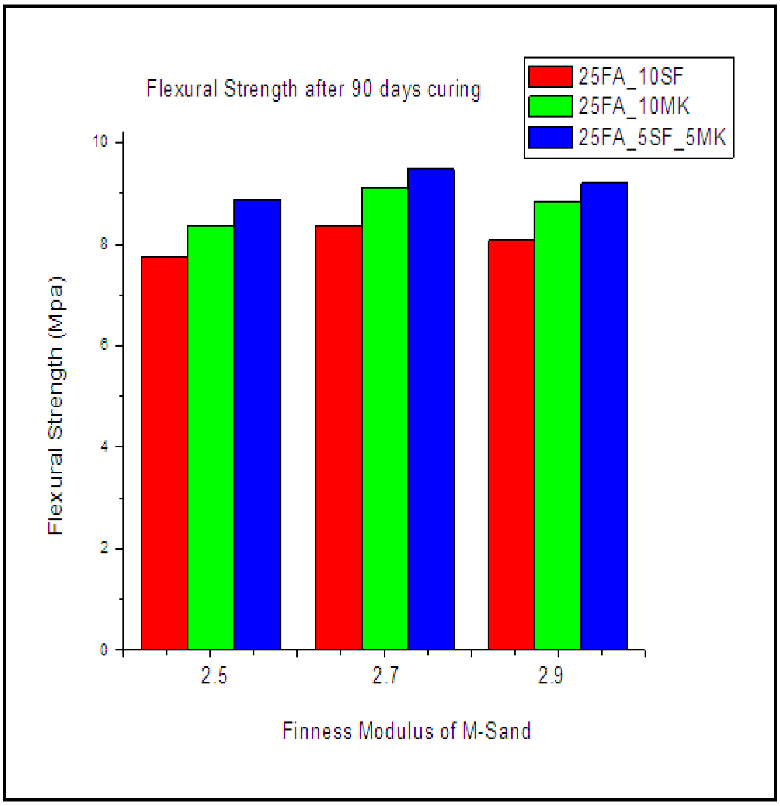

Fig 3. Flexural strength values @ 90 days

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 more 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 flexural strength properties.
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 both fresh and mechanical 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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