Properties of Self Compacting Concrete using GGBS and Manufactured Sand

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***Abstract*: Self - compacting concrete (SCC), flows into place and around obstructions under its own weight, is extensively applied in many construction projects. In recent years, manufactured sand produced by crushing of rock is being identified as a suitable alternative source for river sand in concrete. Mineral admixtures usually added to concrete in large amount to enhance workability of fresh state and durability of concrete in hardened state. This paper covers the effect of replacing river sand by manufactured sand on SCC produced by using ground granulated blast furnace slag (GGBS) as a filler material. Nan Su method is being used for mix design, optimum mix proportion finalised with 10 percent GGBS as replacement for cement at water – powder ratio of 0.34 for M50 grade concrete. The study has shown that SCC with 10 percent GGBS and 30 percent replacement of river sand by manufactured sand indicate fresh SCC within EFNARC guidelines and enhanced strength properties.**

***Keywords*- GGBS, M-Sand, Compressive Strength, SCC**

I. INTRODUCTION

Self – compacting concrete has excellent deformability and segregation resistance which does not require vibration for placing process. In the mix design, the amount of aggregates required is determined and the paste binders is then filled in voids of aggregates to obtain flowability and self–compacting ability [1]. Commonly SCC mixes have greater amount of filler materials like ground granulated blast furnace slag (GGBS), fly ash along with cement which helps in filling air voids between particles. Addition of GGBS will reduce superplasticizer requirement to achieve required slump [2,3,4]. To achieve fluidity, the cement paste should have both fluidity and viscosity [5] and to for higher flowability and stability, high powder volume is required with low water – powder ratio and sufficient superplasticizer [6]. In SCC, the aggregates contribute 60-70 percent of total volume [7]. Aggregate characteristics such as shape, texture and grading influence fresh concrete and hardened concrete properties. The effect of shape and texture of fine aggregate are much more important than the effect of coarse aggregate [9]. Strength and durability properties were increased with proper addition of supplementary cementitious materials like fly ash, GGBS and silica fume [10,11].

II. EXPERIMENTAL WORK

Nan Su method is used for mix design of M50 grade concrete. Trail mixes were carried out for both fresh and hardened properties. Optimum mix finalised was with 10 percent of GGBS replacement for cement at water- powder ratio of 0.34 and use of 1.8 percent of dosage of superplasticizer. Based on fresh properties of SCC, fresh state properties of SCC like flowability and passing ability in accordance EFNARC guidelines were found with different percentage replacement of river sand by M-sand and obtained 30 percent replacement as optimum. It is observed that the increase in percentage reduced the flowability and passing ability of SCC of M50, with 10 percent GGBS and compressive, flexural strength and bond strength of SCC with 10 percent GGBS and 30 percent M-sand are being studied.

Following table shown below is the quantities obtained from mix design.

Table I: Obtained quantities of materials

Sl. No	Material	Quantity (kg/m^3)
1	Cement	485
2	River Sand	980
3	Manufacture Sand	Depends on percent of replacement
4	Coarse Aggregate	776
5	GGBS	30
6	Water	170
7	Superplasticizer	9.29

Table II: Mix indication with respect to percentage replacement by M-Sand

Sl. No.	Mix Designation	Percent of replacement by M-sand
1	M-0	0
2	M-10	10
3	M-20	20
4	M-30	30
5	M-40	40

III. FRESH PROPERTIES

The slump flow test, T_{500mm} test, L-Box test, U- Box test, V-funnel test and J-Ring test are conducted to know the fresh properties of SCC. All above test results were compared with EFNARC guidelines. The test results and respective figures for the tests are shown below.

Table III: Fresh state properties of SCC for different percentage replacement of river sand by M-sand

Sl. No.	Mix	Slump Flow (mm)	T_{500mm} (sec)	L-Box (H_2/H_1)	U-Box(mm)	V-Funnel (sec)	J-Ring (mm)
1	M-0	682	2	0.90	10	4	4
2	M-10	665	3	0.87	13	6	6
3	M-20	651	4	0.83	25	7	7
4	M-30	636	5	0.80	29	8	9
5	M-40	607	6	0.77	30	11	11
	Limits	600-800	2-5	0.8-0.9	0-30	6-12	0-10

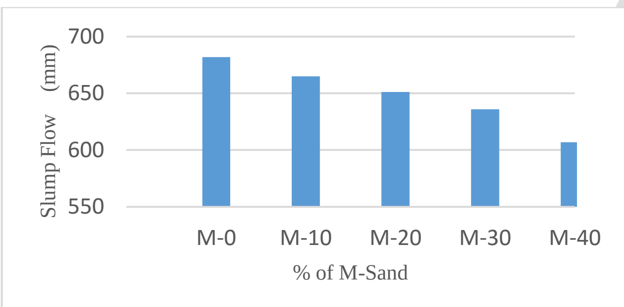

Fig. 1: Slump flow test result values

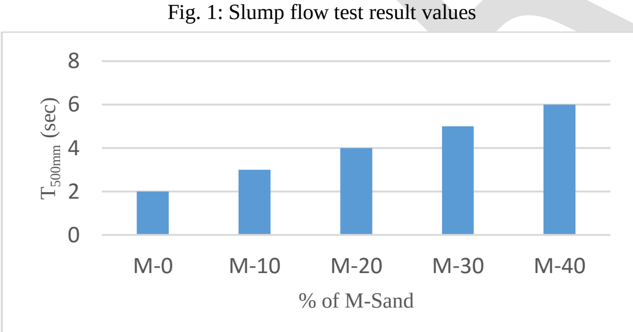

Fig. 2: T_{500mm} test result values

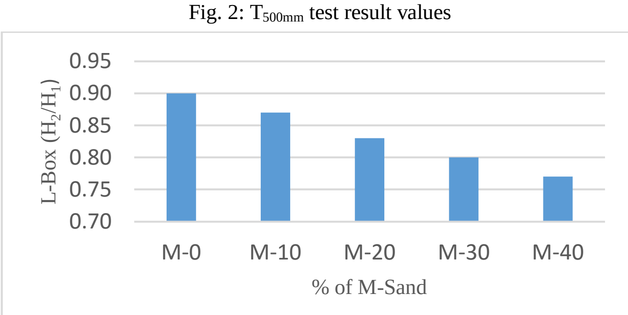

Fig. 3: L box test result values

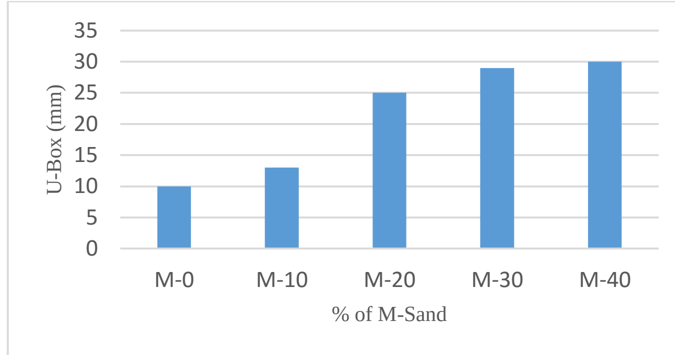

Fig. 4: U box test result values

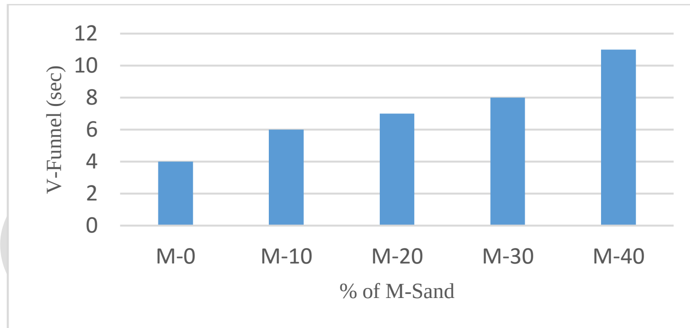

Fig. 5: V funnel test result values

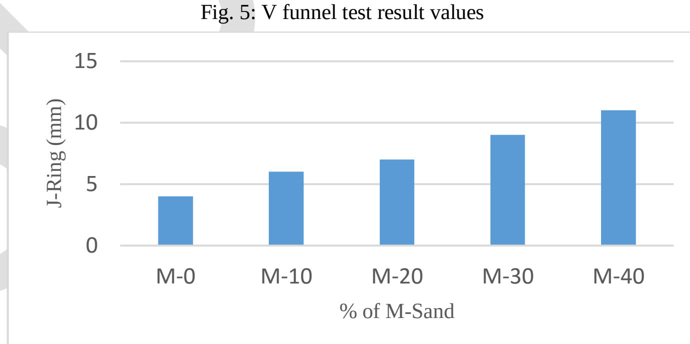

Fig. 6: J ring test result values

From the test results obtained and the variations in figure 1 to figure 6, it has been observed that the reduction in flowability and passing ability were observed with the replacement of river sand by M-sand for a given mix proportion. Maximum replacement of 30 percent has been obtained as optimum. More fines present in the M-sand reduced the flowability and passing ability of SCC.

IV. HARDENED PROPERTIES

In hardened properties tests such as compressive strength, flexural strength, bond test and durability tests were conducted.

a) Compressive strength

The compressive strength results at 28 days curing for different percentage of M-sand is tabulated below.

Table IV: Compressive strength results for different percentage of M-sand

Sl. No.	Name	Percentage of M- Sand	Compressive Strength (N/mm2)	Variation of strength in % with reference mix M0
1	M-0	0%	52.33	0
2	M-10	10%	52.67	0.64
3	M-20	20%	53.41	2.06
4	M-30	30%	55.74	6.51
5	M-40	40%	54.18	3.54

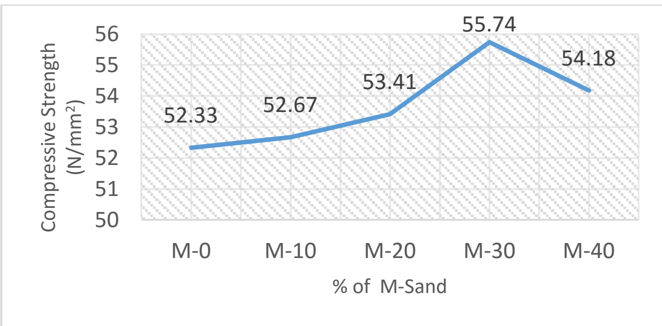

Fig 7: Compressive strength test results

From the figure 7, it has been observed that, for a given mix proportion, replacement of river sand with manufactured sand show gradual increase in compressive strength, varying from 0 percent to 3.54 percent at 40 percent replacement. But the replacement beyond 40 percent reduces the fresh state properties below the EFNARC guidelines.

b) Flexural Strength test

The flexural strength test is carried out for beams at 28 days curing for SCC made with partial replacement of river sand with M-Sand. In following table V results are tabulated.

Table V: Flexural Strength results for different percentage of M-sand

Sl. No.	Name	Percentage of M- Sand	Flexural Strength (N/mm2)	Variation of strength in % with reference mix M0
1	M-0	0%	7.70	0
2	M-10	10%	8.10	5.19
3	M-20	20%	8.40	9.09
4	M-30	30%	8.60	11.68
5	M-40	40%	8.20	6.49

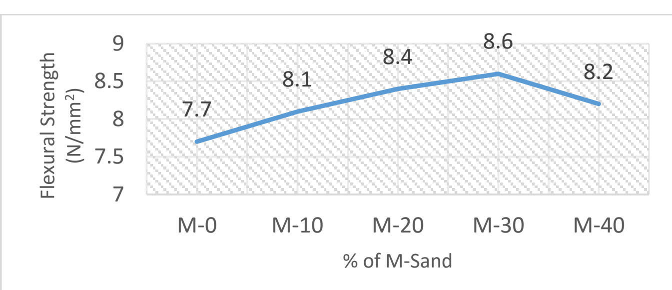

Fig 8: Flexural strength test results

From the figure 8, similar trend in flexural strength has been observed. For a given mix proportion, replacement of river sand with manufactured sand show gradual increase in flexural strength varying from 0 percent to 6.49 percent at 40 percent replacement. Flexural strength results show comparatively better enhancement than compressive strength of SCC, may be due to combined effect of gradation and interlocking.

c) Bond strength test

The bond strength is checked by performing pull out test for specimen kept for 28 days curing for SCC produced with partial replacement of river sand by M-sand. The Bond Strength was tested for 20 mm dia bars embedded with SCC mix.

Table VI: The results of Bond Strength at 28 days curing

Sl. No.	Name	Percentage of M- Sand	Bond Strength (N/mm^2)	Variation of strength in % with reference mix M0
1	M-0	0%	7.95	0
2	M-10	10%	8.27	4.02
3	M-20	20%	8.49	6.79
4	M-30	30%	8.70	9.43
5	M-40	40%	8.59	8.05

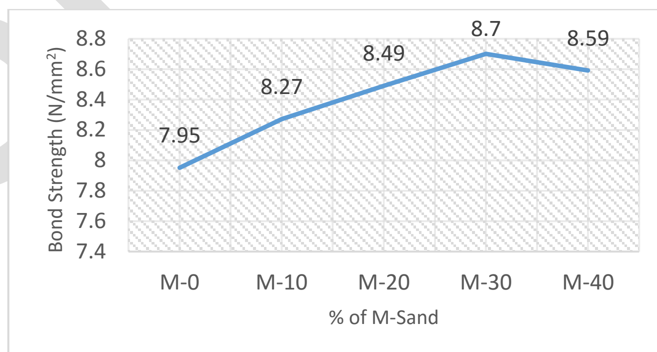

Fig 9: Bond strength test results at 28 days

From the figure 9, similar trend in bond strength has been observed. Bond strength results show comparatively better enhancement than compressive strength of SCC.

d) Sulphate attack test

The sulphate attack test was performed on cubes by immersing cubes in sulphuric solution for 60 days. The test results obtained were compared with normal SCC replaced with M-sand. Results indicate that the SCC with M-sand show marginally reduced loss in weight and loss in strength, even up to 40 percent replacement, 30 percent replacement of river sand by M-sand gives satisfactory results in fresh and hardened state.

Table VII: Sulphate attack test results

S.No.	Cube	Percent Replacement of M-Sand	Avg. weight of cube before sulphate attack	Avg. weight of cube after sulphate attack	Loss of weight in percent	Compressive Strength for 28 days in N/mm^2	Compressive Strength of cube subjected to Sulphate attack in N/mm^2	Percentage loss in Strength
1	M-0	0	8.52	8.35	1.99	52.33	51.06	2.43
2	M-10	10	8.48	8.32	1.88	52.67	51.52	2.18
3	M-20	20	8.45	8.33	1.42	53.41	52.37	1.94
4	M-30	30	8.50	8.41	1.06	55.74	54.86	1.58
5	M-40	40	8.46	8.38	0.94	54.18	53.15	1.90

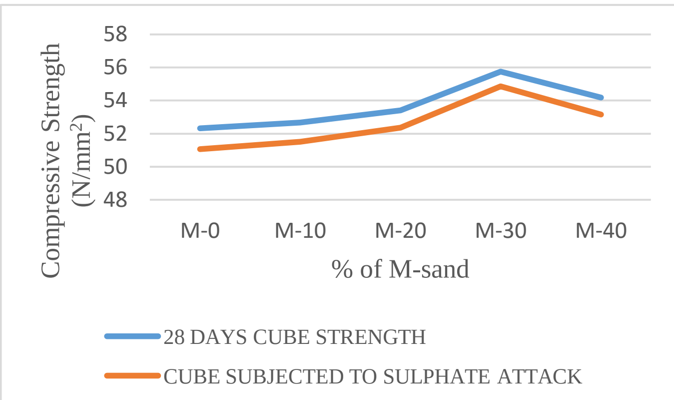

Fig 10: Comparison of cubes with and without effect of Sulphate attack

Relationship between Compressive strength and Bond strength

Regression analysis is carried out for comparison between bond strength and compressive strength. Best fit curve obtained is shown below

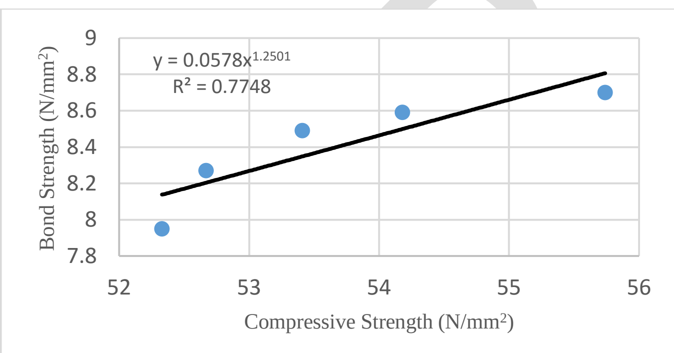

Fig 11: Best fit curve for relationship between compressive strength and bond strength

From the below figure 11, it is seen that the best fit power equation satisfies the relationship of experimental values for compressive strength and bond strength and for the compiled relationship the regression equation is given below.

$$y = 0.0578x^{1.2501}$$

where, y = Bond strength

x = Compressive strength

and coefficient of correlation is given by,

$$r^2 = 0.7748$$

V.CONCLUSIONS

On the basis of test results obtained for SCC with 10 percent GGBS and for different percentage replacement of river sand by manufactured sand for given mix proportion of M50 grade concrete. The following conclusions may be drawn

1. The replacement of river sand by M-sand reduces the workability in the fresh state of concrete due to more finer material.
2. 30 percent replacement of river sand by M-sand gives better compressive strength, flexural strength and bond strength.
3. 30 percent replacement of river sand by M-sand shows marginal improvement in resisting sulphate attack of SCC.

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