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FLEXURAL PROPERTIES OF M 25 GRADE SELF COMPACTING CONCRETE USING MANUFACTURED SAND AND RECYCLED COARSE AGGREGATE

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Abstract--- Self compacting concrete (SCC) can be prepared by increasing the cementitious materials (cement + flyash) and decreasing the content of coarse aggregate. SCC find its application in congested areas where traditional concrete has higher resistance to its flowing ability hence need of SCC increased. In the present study we focused on finding the flexural behaviour of reinforced cement concrete (RCC) beams by replacing with recycled coarse aggregate (RCA) and manufactured sand (MSand). Fresh properties were conducted on the mixes. Two point load test was conducted on beams to find flexural properties namely cracking load, cracking deflection, ultimate load,ultimate deflection of the beams. The beams were cured for a period of 28, 90 days in potable water.

Key words --- SCC, RCC, MSand, RCA, two point load, fresh properties.

I.INTRODUCTION

SCC can flow and fill the gaps of congested reinforcement and corners of moulds without any need of compaction during the placing. But it is not yet utilized in house buildings to large extent with the conception that the use of higher fines and chemical admixtures in SCC leads to more material cost and higher strengths, and also higher paste volume and lower coarse aggregate content known to increase the drying shrinkage of SCC. The increased demand and the consumption of natural materials caused the ecological issues and sudden surge in material cost. In the previous decade variable cost of common sand utilized as fine aggregate in concrete increased the cost of construction. On this premise of past research, manufactured sand offers feasible other option to normal sand. on similar lines recycled coarse aggregate provides alternate for the normal coarse aggregates but these recycled coarse aggregates have high porosity and low specific gravity. This examination is basically centered around the development of normal strength M 25 grade of SCC using manufactured sand and reused coarse aggregate for the utilization of typical building developments.

Nine mixes of various level of replacements in coarse aggregate and fine aggregate using recycled coarse aggregate and manufactured sand has been listed in table1 shown below.

From table MIX3 having 100% natural coarse aggregate and each 50% natural sand and manufactured sand found to have high moment carrying capacity and load carrying capacity.

In this investigation cracking load, cracking deflection, ultimate load, ultimate deflection were found at 28 and 90 days on reinforced cement concrete beams of size 700 mmx150 mm x150 mm.

Table 1: Mix Designations of SCC mixes

Mix type	CA	RCA	Sand	MSand
Mix1	100	0	100	0
Mix2	100	0	75	25
Mix3	100	0	50	50
Mix4	75	25	100	0
Mix5	75	25	75	25
Mix6	75	25	50	50
Mix7	50	50	100	0
Mix8	50	50	75	25
Mix9	50	50	50	50

CA: Coarse aggregateRCA: Recycled coarse aggregateMSand: Manufactured sand

II. EXPERIMENTAL STUDY

A.Materials

Cement used in SCC is of 53 grade having physical properties as shown in table 2 below and corresponding to IS: 12269-1987 [1]. From environment point of view, production of OPC is not an environmentally friendly aspect as it consumes large amount of natural resources and releases a significant amount of green-house gases [2].

Table 2: physical properties of cement

Physical properties	Test result	Test method/ Remarks	Requirement as per IS 12269 (1987)
Specific gravity	3.06	IS 4031(1988) – part 11	_
Fineness (m^2/Kg)	311.5	Manufacturer data	Min.225 m^2/kg
Normal consistency	30%	IS 4031 (1988)- part 4	_
Initial setting time (min)	90	IS 4031 (1988)- part 5	Min. 30 min
Final setting time (min)	220	IS 4031 (1988)- part 5	Max. 600 min
Soundness Lechatelier Expansion (mm) Autoclave Expansion (%)	0.8 0.01	Manufacturer data	Max. 10 mm Max. 0.8%
Compressive strength (MPa) 3 days 7 days 28 days	25 39 57	IS 4031 (1988)- part 6	27 MPa 37 MPa 53 MPa

Class F fly ash produced from Rayalaseema Thermal Power Plant (RTPP), Muddanur, A.P is used as an additive according to ASTM C 618(2003). As per IS 456 (2000) [3], cement is replaced by 30% of fly ash by weight of cementitious material. Studies revealed that high volumes of fly ash can be used in SCC to attain the desired fresh and hardened properties of SCC [4].

Table 3: chemical and physical properties of class F fly ash

Particulars	Class F fly ash
Chemical composition	
% Silica(SiO_2)	65.6
% Alumina(Al_2O_3)	28.0
% Iron Oxide(Fe_2O_3)	3.0
% Lime(CaO)	1.0
% Magnesia(MgO)	1.0
% Titanium Oxide (TiO_2)	0.5
% Sulphur Trioxide (SO_3)	0.2
Loss on Ignition	0.29
Physical properties	
Specific gravity	**2.13**
Fineness (m^2/Kg)	**360**

Guru Jawahar et al. [5] studied the effect of coarse aggregate blending on fresh properties of SCC and proposed a typical range of coarse aggregate content suitable for a particular coarse aggregate blending made with 20 mm and 10 mm size aggregates to obtain successful SCC. In our study crushed coarse aggregates of size 12.5 mm are used. Bulk specific gravity in oven dry condition and water absorption of the natural coarse aggregate 12.5mmare 2.58 and 0.3% respectively. Recycled coarse aggregate used has bulk specific gravity of 2.49 and water absorption of 0.45%.Fine aggregate used are natural sand, Bulk specific gravity at oven dry condition and water absorption of the sand) are 2.62 and 1% respectively. Manufactured sand has specific gravity and water absorption 2.4 and 1.2%.

B. Mix design

In designing the SCC mix, it is most useful to consider the relative proportions of the key components by volume rather than by mass [6]. Several methods exist for the mix design of SCC. The general purpose mix design method was first developed by Okamura and Ozawa [7]. In this study, the key proportions of constituents of SCC mixes were obtained by using the SCC mix design tool (JGJ_SCCMixDesign.xls) [8].

Table 4: Mix proportions of constituent materials of SCC mixes

Mix type	Binder Kg/m^3	Cement kg/m^3	Fly ash kg/m^3	Water l/m^3	12mm Kg/m^3 (CA)	12mm kg/m^3 (RCA)	Sand Kg/m^3	MSand Kg/m^3	SP l/m^3
Mix1	501	350.7	150.3	180.36	721.6	0	863.4	0	6.01
Mix2	501	350.7	150.3	180.36	721.6	0	647.55	215.85	6.01
Mix3	501	350.7	150.3	180.36	721.6	0	431.7	431.7	6.01
Mix4	501	350.7	150.3	180.36	541.2	180.4	863.4	0	6.01
Mix5	501	350.7	150.3	180.36	541.2	180.4	647.55	215.85	6.01
Mix6	501	350.7	150.3	180.36	541.2	180.4	431.7	431.7	6.01
Mix7	501	350.7	150.3	180.36	360.8	360.8	863.4	0	6.01
Mix8	501	350.7	150.3	180.36	360.8	360.8	647.55	215.85	6.01
Mix9	501	350.7	150.3	180.36	360.8	360.8	431.7	431.7	6.01

C.Fresh properties

Fresh properties like slump flow , V-funnel, L-box are performed to get the required flow ability to the concrete. The values are in line with the specifications as shown in table 5 and follows EFNARC. 2002. Specifications[4]. According to Bonen and Shah 2005 [9], the key factor for a successful development of SCC is to clearly understand the role of the different constituent material in the mix and their effects on the fresh and hardened properties of SCC.

Table 5: Fresh properties of trial mixes

Mix type	SLUMP FLOW (mm)	V- FUNNEL (SEC)	L-BOX TEST (h2/h1) ratio
MIX1	690	6.2	0.97
MIX2	675	7.3	0.89
MIX3	656	10.4	0.82
MIX4	682	6.6	0.95
MIX5	669	7.9	0.86
MIX6	652	10.9	0.81
MIX7	678	7.1	0.91
MIX8	661	8.4	0.83
MIX9	645	11.1	0.80

D.Experimental setup

Compressive test has to be performed on cube specimens of size 150mm x 150 mm x 150mm with curing period of 28 and 90 days in compression testing machine (CTM). Three specimens were casted and tested for each age and each mix.

Flexural test has to be performed on beams of size 700mmx150mmx150mm with reinforcement having four main bars of diameter of 10mm and stirrups of diameter of 8mm. A clear cover of 30mm was provided. The center to center distance between the stirrups is 80mm. The effective span of the beam is 600mm. The beams were tested on a manually operated loading frame having a capacity of 100kN. Two point load test has to be performed at a distance of L/3 from the either ends. Three dial gauges of which two were fixed at a distance L/3 from each ends and third one at the centre. Load has to be applied manually using hydraulic jack. Deflections values has to be noted for every 5kN loading.

Figure 1: Two point load setupFigure 2: failure of beam under two point load

III. RESULTS AND DISCUSSIONS

A.Mechanical properties

From the table 6 we observe that the compressive strength of MIX3 is higher than the other mixes this is mainly attributed by increase in proportion of manufacturing sand because of silica content present in the manufacturing sand. The use of recycled coarse aggregate slightly affects the strength of concrete because of increase in porosity and low specific gravity and high water absorption. Hence we can justify the mix with low recycled coarse aggregate and higher manufacturing sand gives you best strength which in our case is MIX3. The test procedures follow IS 516 (1991) [10] specifications.

Table 6: compressive strength of various mixes

MIX TYPE	COMPRESSIVE STRENTH(MPA)	
	28 DAYS	90 DAYS
MIX1	32.8	45.4
MIX2	33.2	46.1
MIX3	35.6	48.4
MIX4	31.6	44.8
MIX5	32.4	45.4
MIX6	34.3	47.2
MIX7	30.2	42.6
MIX8	31.8	43.9
MIX9	32.1	45.8

B.Load carrying capacity

From the table 7 we can observe that the load at first crack is high for the MIX3 for 28 days as compared with the other mixes this is mainly due to the presence of high percentage of manufacturing sand in which it contains high silica content hence higher strength. The same may be applicable for 90 days but with higher strength.

On similar lines the ultimate load carrying capacity of increases with the use of manufactured sand and decreases with the use of recycled coarse aggregates hence MIX3 has higher load carrying capacity because of 100% recycled coarse aggregate and 50% manufacturing sand making it ideal among all the mixes which is applicable for 28, 90 days from table8.

Table 7: first crack load at 28 and 90 days of curing

MIX TYPE	FIRST CRACK LOAD @28 DAYS (kN)	FIRST CRACK LOAD @90 DAYS (kN)
MIX1	20.9	29
MIX2	23.51	32.8
MIX3	25.38	34.5
MIX4	17.53	26.3
MIX5	21.35	30.4
MIX6	24.51	33.68
MIX7	17.34	25.8
MIX8	20.84	28.43
MIX9	24.02	32.31

Table 8: ultimate load at 28 and 90 days of curing

MIX TYPE	THEORITICAL ULTIMATE LOAD @28 DAYS (kN)	EXPERIMENTAL ULTIMATE LOAD @28 DAYS (kN)	THEORITICAL ULTIMATE LOAD @90 DAYS (kN)	EXPERIMENTAL ULTIMATE LOAD @90 DAYS (kN)
MIX1	31.68	41.93	32.73	46.96
MIX2	31.73	41.99	32.77	47.03
MIX3	31.98	42.31	32.89	47.27
MIX4	31.54	41.75	32.69	46.76
MIX5	31.64	41.87	32.73	46.90
MIX6	31.85	42.14	32.83	47.20
MIX7	31.36	41.51	32.55	46.49
MIX8	31.57	41.78	32.63	46.79
MIX9	31.60	41.82	32.75	46.84

C.Deflection of beamunder flexure

The beams are subjected to two point loading and deflection values has to be noted for first crack and final crack. From the table 9, 10 we can observe that MIX3 has higher deflection before first crack because of increase in load carrying capacity which causes higher deflection.

Table 9: first crack deflection at 28 and 90 days of curing

MIX TYPE	FIRST CRACK DEFLECTION @28 DAYS (mm)	FIRST CRACK DEFLECTION @90 DAYS (mm)
MIX1	1.32	1.12
MIX2	1.48	1.33
MIX3	1.54	1.39
MIX4	1.13	0.97
MIX5	1.36	1.15
MIX6	1.52	1.35
MIX7	1.14	0.96
MIX8	1.34	1.14
MIX9	1.5	1.26

Table 10: ultimate deflection at 28 and 90 days of curing

MIX TYPE	THEORITICAL DEFLECTION @ 28 DAYS (mm)	EXPERIMENTAL DEFLECTION @ 28 DAYS (mm)	THEORITICAL DEFLECTION @ 90 DAYS (mm)	EXPERIMENTAL DEFLECTION @ 90 DAYS (mm)
MIX1	2.1	2.66	1.79	2.53
MIX2	2.0	2.64	1.75	2.51
MIX3	1.94	2.57	1.71	2.46
MIX4	2.22	2.69	1.77	2.53
MIX5	2.01	2.66	1.76	2.52
MIX6	1.97	2.61	1.73	2.49
MIX7	2.17	2.74	1.81	2.58
MIX8	2.03	2.70	1.79	2.56
MIX9	2.02	2.68	1.75	2..51

IV. REGRESSION MODEL TO ESTIMATE THE FLEXURE STRENGTH

The following regression models were established to estimate the flexure strength of concrete and the models are tested with experimental results , the authors would like to develop regression models to estimate the flexure strength as function of cube compressive strength. For this linear regression models are plotted to find the relation between flexure and compressive strength for 28, 90 days.

$f_{cr} = 6.59 + 0.026\, f_{ck}$, $R^2 = 0.995$

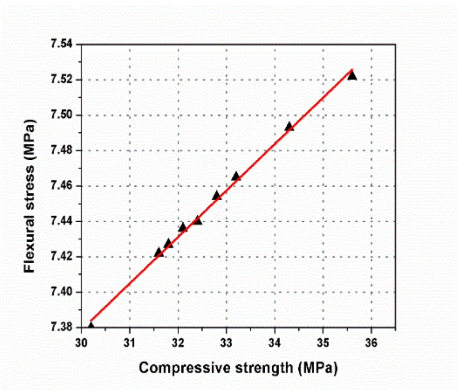

Figure 3 28 days compressive strength vs flexural stress

$f_{cr} = 7.26 + 0.023\, f_{ck}$, $R^2 = 0.908$

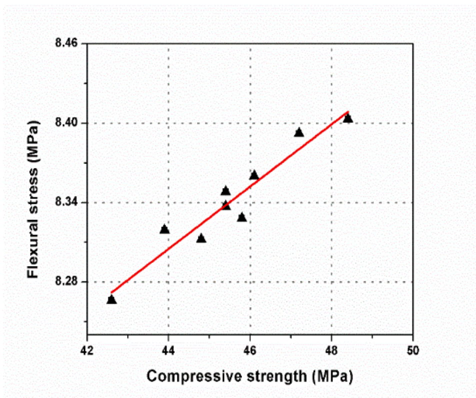

Figure 4 90 days compressive strength vs flexural stress

$f_{cr} = 5.27 + 0.066\, f_{ck}$, $R^2 = 0.975$

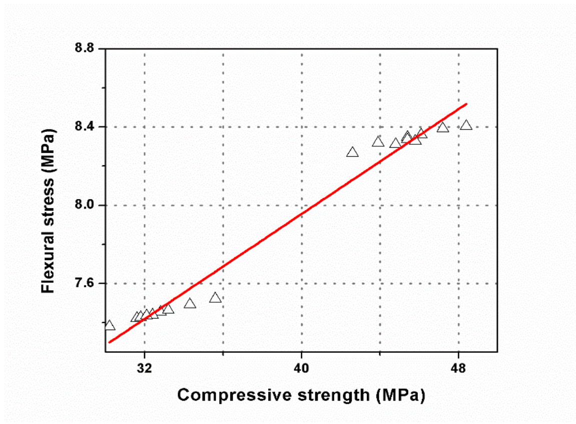

Figure 5 overall compressive strength vs flexural stress

f_{cr} : flexural stressf_{ck}: compressive strength

V.CONCLUSIONS

1. M 25 grade of SCC was performing enhanced mechanical properties at later ages as compared to that same grade of regular concrete due to pozzolanic action of class F fly ash.
2. The increase in manufactured sand replacement levels reduced the SCC fresh properties due to the increase of yield stress caused by particles of manufactured sand.
3. The increase in replacement level of manufactured sand enhances the mechanical properties of SCC due to filling ability of manufactured sand and its silica content.
4. The increase in replacement level of recycled coarse aggregate has reduced the strength slightly because of ageing effect of aggregates and its effect on fresh properties is negligible.
5. It is concluded that manufactured sand can be partially replaced in the sand to certain extent and in case recycled coarse aggregate increase in percentage causes slight reduction in strength and negligible effect on SCC so they can be used to address the environmental issues.
6. Of all the nine mixes MIX3 is found to be have higher flexural strength than other mixes because of manufactured sand and natural coarse aggregates.
7. The mode of failure in RCC beams are "Flexure Failure"

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