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Study on Properties of SCC with Partial Replacement of Cement by GGBFS and Fly Ash

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***Abstract* - This paper presents experimental study on the properties of self-compacting concrete (SCC) amended with two additional cementitious materials (fly ash and slag) on the mechanical performance of self-compacting concrete (SCC). Portland cement (PC) was replaced with fly ash (FA), Ground Granulated Blast Furnace Slag (GGBFS). The effect of these admixtures on the fresh and hardened SCC of various mix proportions was studied. It was observed there was only very small difference in workability and strength of SCC when the cement was partially (30%) replaced by GGBFS and Fly ash at various proportions. From the results obtained GGBFS replacement in concrete, considerably increase the strength of concrete.**

Keywords: self-compacting concrete, fly ash, Ground Granulated Blast Furnace Slag, Workability, Strength.

I. INTRODUCTION

The Japanese found the Self Compacting Concrete by 1980 to overcome the compaction problems faced by civil engineering community during concrete work in closely reinforced sections as there were very minimum or no spaces available for proper compaction. The main advantage of SCC is that it compact by its own weight which ensures the strength of structural members and reduce the duration of construction to some extent. Besides its advantages, the SCC is being suffered from high cost as it requires large amount of cement and chemical admixtures that act as plasticizers. In order to make SCC economical, cement can be partially replaced by some other cementitious material which are available at low cost. If we use industrial by products it may lead to cleaner and greener productions.

Flyash is a thermal power plant waste ash produced after burning the coal. In the year 2014-2015 India has produced 184.14 million tons of flyash. Granulated Blast Furnace Slag is acquired by quenching the molten ash from the furnace with the help of water. During this process, the slag gets fragmented and transformed into amorphous granules (glass), meeting the requirement of IS 12089:1987 (manufacturing specification for granulated slag used in Portland Slag Cement). The granulated slag is ground to desired fineness for producing GGBFS. The main objective of this research is to use flyash and GGBFS as partial replacement of cement in SCC so as minimize not only the cost but also green disposal of industrial waste products.

II.MATERIALS AND MIX PROPORTIONS

The materials for production of SCC include Ordinary Portland Cement, Coarse & Fine aggregates, Water, Plasticizers and fly ash, GGBFS as well. Flyash was obtained from Mettur Thermal Power Plant and GGBFS was collected from JSW, Mettur. Table 1 shows the physical properties of materials whereas Table 2 shows the chemical composition of materials.

Super plasticizers were essential components of SCC to provide necessary workability. In this study Master Glenium SKY 8233 of Master Builders Solutions was used. It was an admixture of a new generation based on modified polycarboxylic ether. The product had been primarily developed for applications in high performance concrete where the highest durability and performance was required.

In order to find out the effect on properties of self-compacting concrete with partial replacement of cement by GGBFS and fly ash various trial mixes were derived from the final SCC design mix. In the trial mix 30% of ordinary Portland cement was replaced by various proportions of GGBFS and fly ash. ie., 30% of cement was partially replaced by Fly ash and GGBFS. In that 30% the variation of % of fly ash and GGBFS were given in the table 3.

III.METHODOLOGY

The material properties were determined at first, followed by proportioning of different mixes for SCC. The specimen type and size of mould for testing are listed in table 4 and in table 5 number of specimen casted. Slump flow test, L-Box test, and V-Funnel test were carried out for fresh concrete by conducting at least 3 trials. Compression test, Split tensile test and Flexural test were adopted for ascertaining hardened concrete properties.

TABLE I PHYSICAL PROPERTIES OF MATERIALS

Properties	Cement	FA	CA	GGBFS	Flyash
Specific Gravity	3.15	2.67	2.60	2.62	2.12
Normal Consistency (%)	32	NA	NA	NA	NA
Initial Setting Time (minutes)	45	NA	NA	NA	NA
Final Setting Time (minutes)	320	NA	NA	NA	NA
Size	Pass through 90μm sieve	Pass through 4.75mm sieve	Passing through 12.5mm and retained on 10mm	NA	NA
Water absorption	NA	1.11%	0.5%	NA	NA

TABLE II CHEMICAL PROPERTIES OF MATERIALS

Chemical Constituents	OPC	FLY ASH	GGBFS
SiO_2	21.1	43.4	40.0
Al_2O_3	4.6	18.5	13.5
CaO	65.1	4.3	39.2
MgO	4.5	0.9	3.6
Fe_2O_3	2.0	29.9	1.8
SO_3	2.8	1.2	0.2

TABLE III MIX PROPORTIONS OF SCC

Mix code	NM	SCC 1	SCC 2	SCC 3	SCC 4	SCC 5	SCC 6
Cement (Kg/m^3)	500	500	350	350	350	350	350
Fine aggregate (Kg/m^3)	830	830	830	830	830	830	830
Coarse aggregate (Kg/m^3)	830	830	830	830	830	830	830
Water (litres/m^3)	200	200	200	200	200	200	200
Super Plasticizer (litres/m^3)	6	6	6	6	6	6	6
% of Fly ash	0	0	100	0	50	75	25
Fly ash (Kg/m^3)	0	0	150	0	75	112.5	37.5
% of GGBFS	0	0	0	100	50	25	75
GGBFS (Kg/m^3)	0	0	0	150	75	37.5	112.5

TABLE IV SPECIMEN TYPE AND SIZE OF MOULD

S.No.	Properties	Type of Specimen	Size (mm)
1	Compressive strength	Cube	150 x 150 x 150
2	Split tensile strength	Cylinder	150 x 300
3	Flexural strength	Prism	500 x 100 x 100

TABLE V NUMBER OF SPECIMEN CASTED

Type	Number of moulds	Remarks
Cube	36	(6 No's. of trial mix X 6 No's)
Cylinder	24	(6 No's. of trial mix X 4 No's)
Prism	24	(6 No's. of trial mix X 4 No's)

IV. TESTING TECHNIQUES

Slump flow test is used to measure the horizontal flow of concrete in the absence any obstacles. This test was done using a slump cone without any compaction. When the slump cone was removed the sample collapsed and diameter of spreading was measured. L-box test was done to determine the flowing and blocking nature of SCC. The time taken by the concrete to flow a distance of 200mm (T-20) and 400mm (T-40) into the horizontal section was measured. To measure the viscosity of SCC V-Funnel test was done. The results of fresh concrete test were given in table 6.

The hardened concrete cubes were tested for its compressive strength which is being the important characteristics of any concrete. These specimens were tested by compression testing machine after 7 days curing and 28 days curing. Load was applied gradually at the rate of 140 kg/cm^2 per minute till the Specimens fails. The cylinder specimens were tested by compression testing machine after 7 days curing or 28 days curing to measure their tensile strength indirectly. The specimens were placed longitudinal direction in the machine. Load was applied gradually at the rate of 140 kg/cm^2 per minute till the Specimens fails. Load at the failure was noted as P. Using the formula $T = 2P/\pi DL$ tensile strength of specimen was found out. The bending properties were obtained from flexure test. Table 7 showed the results of hardened concrete.

TABLE VI RESULTS OF FRESH CONCRETE

Mix Code	Slump flow (mm)	L –BOX (h_2/h_1)	V - Funnel time (sec)
NM	650	0.8	10.2
SCC 1	650	0.9	8.6
SCC 2	700	0.96	8.4
SCC 3	660	0.82	9.8
SCC 4	675	0.90	9.3
SCC 5	685	0.92	9.0
SCC 6	670	0.86	9.5

TABLE VII RESULTS OF HARDENED CONCRETE

Mix Code	Compressive Strength (N/mm^2)		Tensile Strength (N/mm^2)		Flexural Strength (N/mm^2)	
	7 Days	28 Days	7 Days	28 Days	7 Days	28 Days
NM	22.91	32.41	2.40	3.01	2.77	3.92
SCC01	22.91	32.41	2.40	3.01	2.77	3.92
SCC02	22.33	31.73	2.36	2.98	2.70	3.84
SCC03	24.66	33.46	2.54	3.15	2.98	4.05
SCC04	23.24	32.84	2.47	3.08	2.81	3.98
SCC05	22.84	32.08	2.36	3	2.77	3.88
SCC06	23.86	33.11	2.49	3.11	2.89	4

V. RESULTS AND DISCUSSION

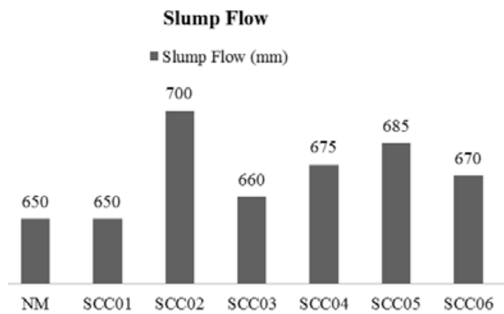

Fig.1 Variation of Slump flow

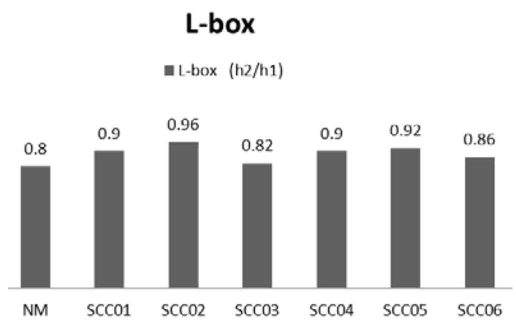

Fig.2 Variation of blocking ratio in L-box

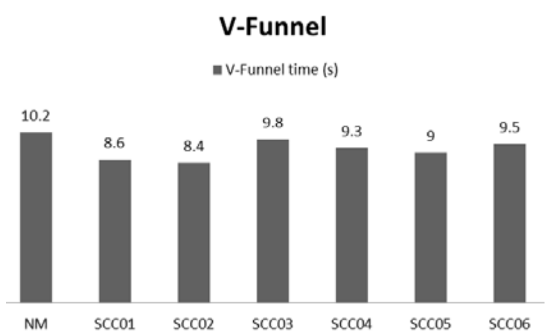

Fig.3 Variation of V-Funnel test

The Slump Flow test can give an indication as to the consistency, filling ability and workability of SCC. The SCC was assumed of having a good filling ability and consistency if the diameter of the spread reaches values between 650mm to 800mm. The results indicated that SSC mixes were having adequate consistency, filling ability and workability. Blocking of the SCC mixture happens when the L-box blocking ratio is less than 0.8. Blocking ratios of different SCC were shown in Fig. 2. Blocking ratio (h2/h1) must be between 0.8 and 1.00. All the mixtures of SCC had fallen in desired range as per EFNARC standards. The V-funnel flow times were in the range of 8.4–10.2 s. It was suggested by EFNARC Committee that 11 and 15 s for lower and upper limits of V-funnel time, respectively, were acceptable for designing the appropriate SCC mixtures. In Fig. 3, test results of this investigation indicated that all SCC mixtures meet the requirements of allowable flow time.

Properties of hardened SCC of various mix proportions were as that of SCC without any replacement of OPC. This ensures that replacement of OPC by fly ash and GGBFS did not produce any significant change in terms of strength of SCC. Figure 4 shows the trend.

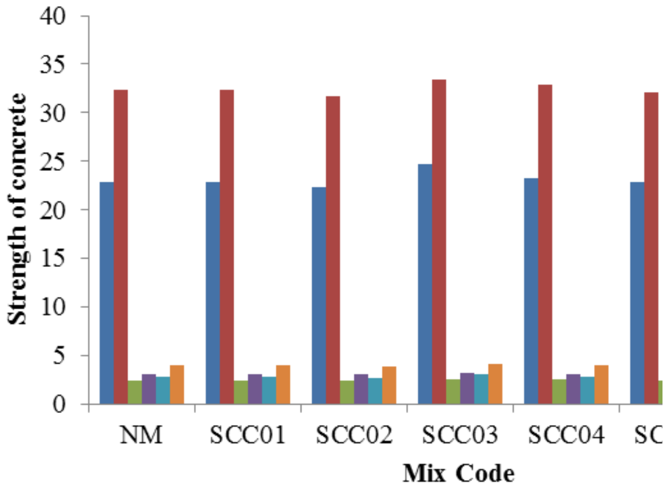

Fig.4 Comparison of various strengths of hardened SCC

VI. CONCLUSION

1. It was observed there was only very small difference in workability and strength of SCC when the cement was partially (ie.30%) replaced by GGBFS and Fly ash at various proportions.
2. From the result obtained from the mix SCC 2 (ie. when the cement was replaced 30% completely by Fly ash alone) the fresh properties of SCC enhances to greater extent compared to other mixes.
3. From the result obtained from the mix SCC 3 (ie. when the cement was replaced 30% completely by GGBFS alone) the hardened properties of SCC enhances to some extent compared to other mixes.
4. The GGBFS replacement in concrete, considerably increase the strength of concrete.
5. The Fly ash replacement in concrete, considerably increase the workability of concrete.
6. The optimum replacement for 30% of cement was in the proportion of 50:50 GGBFS and Fly ash in that 30% of cement because it comprise both workability and strength behaviour when compare to other mixes.

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