

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

¹S.Vinodhkumar, ²M.Arunkumar, ³P.Kulanthaivel, ⁴K.Sampathkumar

^{1,2,3,4}Assistant Professor

Department of Civil Engineering

Kongu Engineering College, Perundurai-638052

E-mail: ¹vinodh.civil@kongu.edu, ²arunkumarm.civil@kongu.edu, ³kulanthaivel.civil@kongu.edu,
⁴sampathkumar.civil@kongu.edu,

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 that there was a 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, it is concluded that GGBFS replacement in concrete considerably increases the strength of concrete.

Keywords: *Self-Compacting Concrete, Fly Ash, Ground Granulated Blast Furnace Slag, Workability, Strength*

INTRODUCTION

The Japanese developed 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 minimal or no spaces available for proper compaction.

The main advantage of SCC is that it is compact by its own weight as this ensures the strength of structural members and reduction in the duration of construction to some extent. Besides its advantages, the SCC is being suffered from high cost as it requires a 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 cement-like materials that are available at a 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 the 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 enable green disposal of industrial waste products.

MATERIALS AND MIX PROPORTIONS

The materials for production of SCC include Ordinary Portland Cement, Coarse

& Fine aggregates, Water, Plasticizers and fly ash, and 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 fly ash and GGBFS were given in the table 3.

Table 1: 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 2: Chemical Properties of Materials

Chemical Constituents	OPC	FLY ASH	GGBFS
SiO ₂	21.1	43.4	40.0
Al ₂ O ₃	4.6	18.5	13.5
CaO	65.1	4.3	39.2
MgO	4.5	0.9	3.6
Fe ₂ O ₃	2.0	29.9	1.8
SO ₃	2.8	1.2	0.2

Table 3: Mix Proportions of SCC

Mix code	NM	SCC 1	SCC 2	SCC 3	SCC 4	SCC 5	SCC 6
Cement (Kg/m³)	500	500	350	350	350	350	350
Fine aggregate (Kg/m³)	830	830	830	830	830	830	830
Coarse aggregate (Kg/m³)	830	830	830	830	830	830	830
Water (litres/m³)	200	200	200	200	200	200	200
Super Plasticizer (litres/m³)	6	6	6	6	6	6	6
% of Fly ash	0	0	100	0	50	75	25
Fly ash (Kg/m³)	0	0	150	0	75	112.5	37.5
% of GGBFS	0	0	0	100	50	25	75
GGBFS (Kg/m³)	0	0	0	150	75	37.5	112.5

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; a number of specimens are 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 4: 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 5: Number of Specimen Casted

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

Table: 6 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: 7 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

TESTING TECHNIQUES

Slump flow test is used to measure the horizontal flow of concrete in the absence of any obstacles. This test was done using

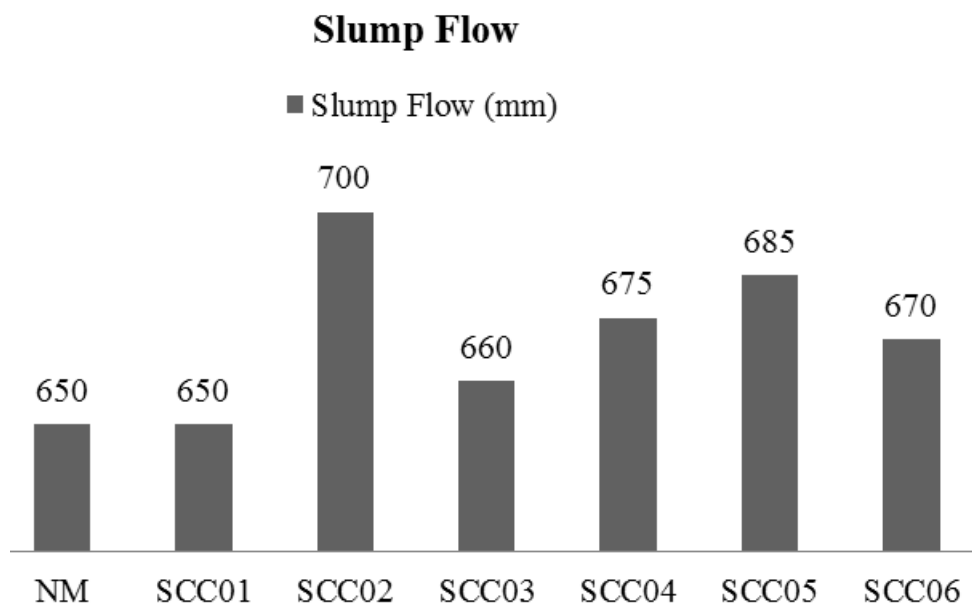
a slump cone without any compaction. When the slump cone was removed, the sample collapsed and diameter of spread was measured. L-box test was done to

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 undertaken. The results of fresh concrete test are given in table 6.

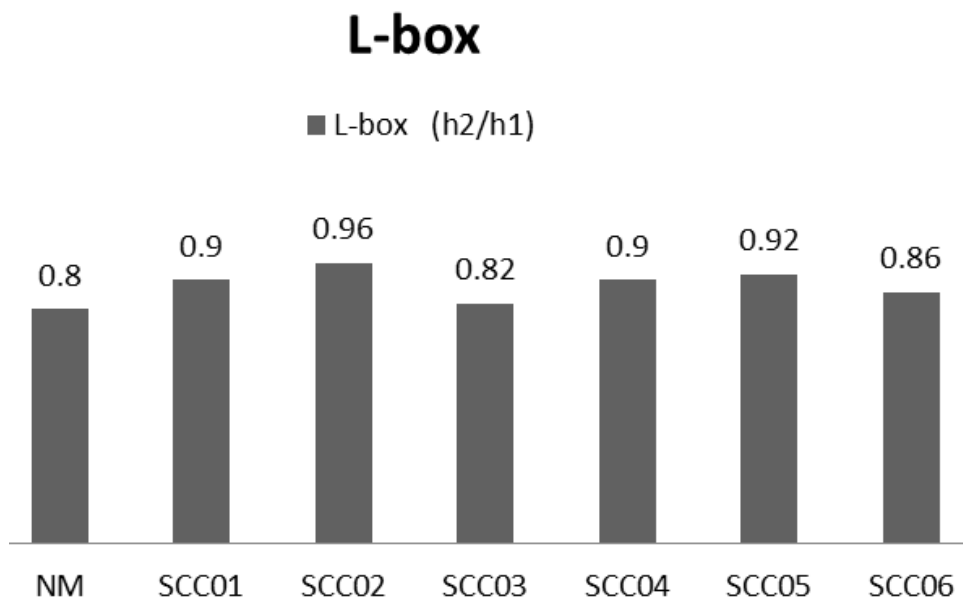
The hardened concrete cubes were tested for their compressive strength, which is an important characteristic of any concrete. These specimens were tested by compression testing machine after curing for 7 days curing and 28 days. Load was applied gradually at the rate of 140

kg/cm² per minute till the Specimens failed. The cylinder specimens were tested by compression testing machine after curing for 7 days or 28 days to measure their tensile strength indirectly. The specimens were placed at longitudinal direction in the machine. Load was applied gradually at the rate of 140 kg/cm² per minute till the specimens failed. 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.

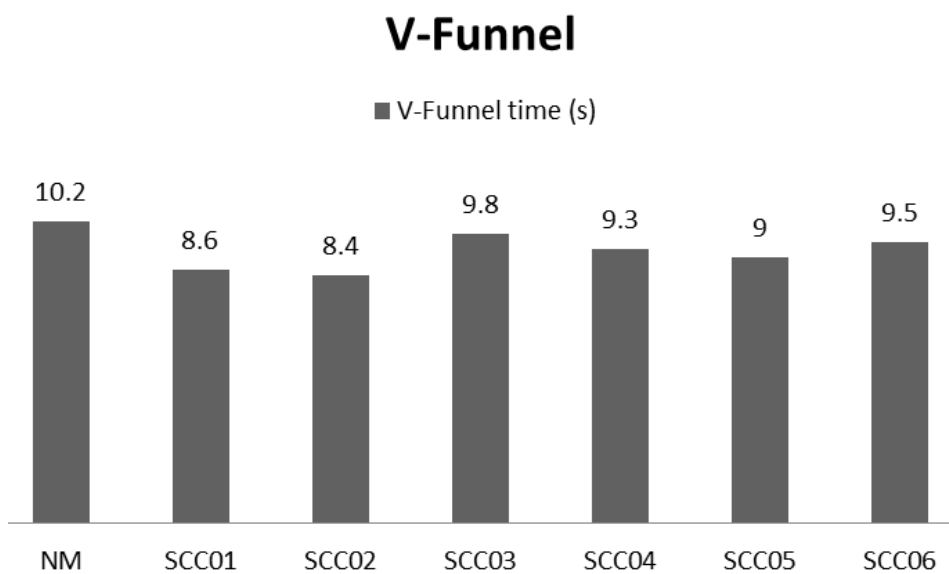
RESULTS AND DISCUSSION



Graph 1: Variation of Slump flow



Graph 2: Variation of blocking ratio in L-box

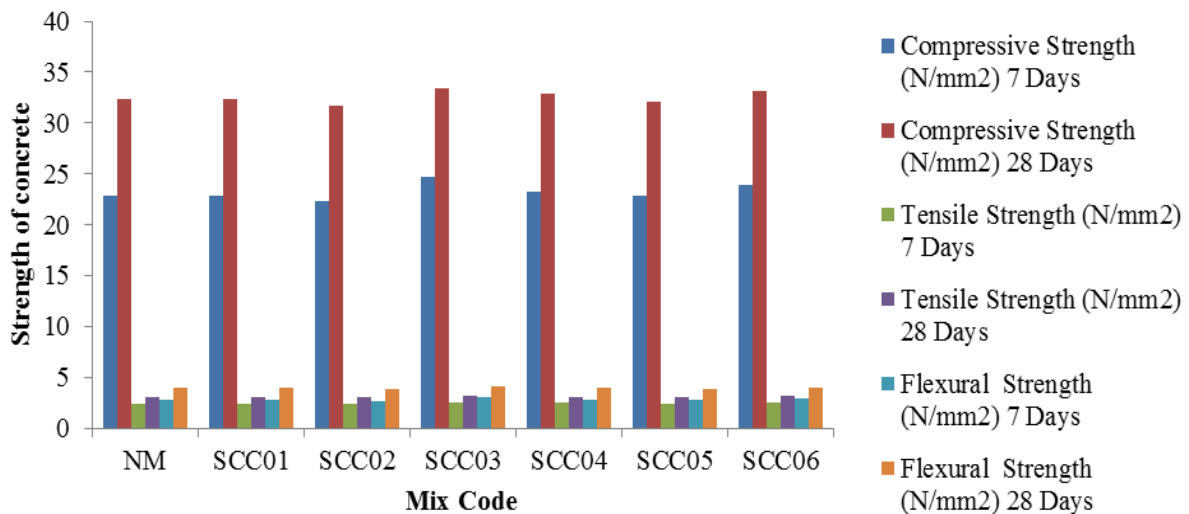


Graph 3: Variation of V-Funnel test

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 a value between 650mm and 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 is shown in Graph 2. Blocking ratio (h_2/h_1) 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 seconds. It was suggested by EFNARC Committee that 11 and 15 seconds respectively should be the lower and upper limits of V-funnel time for designing the appropriate SCC mixtures. In graph 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 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. Graph 4 shows the trend.



Graph 4: Comparison of Various Strengths of Hardened SCC

CONCLUSION

1. It was observed there was only very small difference in workability and strength of SCC when the cement was partially (i.e. 30%) replaced by GGBFS and Fly ash at various proportions.
2. From the result obtained from the mix, SCC 2 (i.e. when the cement was replaced 30% 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 (i.e. when the cement was replaced 30% by GGBFS alone) the hardened properties of SCC enhances to some extent compared to other mixes.
4. The GGBFS replacement in concrete considerably increases its strength.
5. The fly ash replacement in concrete considerably increases the workability of concrete.
6. The optimum replacement for 30% of cement was in the proportion of 50:50, i.e. GGBFS and fly ash in 30% of cement. This mixture

results in better workability and strength behaviour when compared to other mixes.

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