EFFECT OF GGBS AND SILICA FUME ON STRENGTH AND DURABILITY OF SELF COMPACTING CONCRETE

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Abstract—Self-Compacting Concrete is one of innovative and most revolutionary development in concrete research; this concrete is able to flow on its own weight and to fill the most restricted places of the form work without vibration. Such concrete can accelerate the placement, reduce the labour requirements needed for consolidation, finishing and eliminate environmental pollution. The primary objective of this study is to make use of Ground granulated blast furnace slag (GGBS) and silica fume as a replacement of cement and understand its effects on the fresh properties, compressive strength and split tensile strength weathering. The Use of GGBS and silica fume normally reduces the environmental hazard but makes the concrete economical as well. The study also intended to quantify the amount of Ground granulated blast furnace slag (GGBS) to be added to the concrete according to the value of concrete properties Measured. In the present article summarizes the improvement in certain fresh properties even with mechanical properties was found to be improved with the addition of GGBS and silica fume as admixtures at different ages of concrete curing.

Keywords—Self-Compacting Concrete; GGBS; Silica fumes; Workability; Mechanical and Durability.

I. INTRODUCTION

The development of self-compacting concrete (SCC) has been one of the most important development in the building industry. The purpose of this concrete concept is to decrease the risk due to human factor. Also with an addition of admixtures, great improvement in the pore structures, also compactability was found to be affected by the characteristics of the materials and the mix proportions hence, it is necessary to arrive the proper mix design procedure. SCC was first developed in the late 1980's by Japan researchers. The flowability and mix stability of the SCC are determined primarily by the interactions between the powder (cement and additions with a particle diameter < 0.125 mm), water and plasticizer. The gradation of the individual size groups in the overall grading curve also affects the property of the concrete of not being blocked by the reinforcement. There is no standard method for SCC mix design. Mix designs often use volume as a key parameter because of the importance of the need to over fill the voids between the aggregate particles. Some methods try to fit available constituents to an optimised grading envelope. Another method is to evaluate and optimise the flow and stability of the paste and then the mortar fractions before the coarse aggregate is added and whole SCC mix tested. This paper analyses characteristics and properties of concrete mixtures with ground granulated blast furnace slag (GGBS) and silica fumes (SF).

II. MATERIAL CHARACTERIZATION

Cement used is 53 grade Ordinary Portland cement and its Physical properties obtained from the lab tests are presented in Table I. Locally available river sand of specific gravity 2.64, fineness modulus 2.8, Bulk density 15.25 KN/m3 and conforming to zone II was used as fine aggregate. The crushed granite stone with a maximum size of 12 mm, specific gravity 2.67, bulk density 16.80 KN/m3, flakiness particles 12.2% and well graded was used as coarse aggregate. Both the aggregate used conformed to IS: 383-1970 specification for coarse and fine aggregates from natural sources for concrete. The superplasticiser used in the study is Master Glenium B233. The physical properties of GGBS and silica fume are given in Table II.

Table I. Physical properties of ordinary portland cement

Sl.No	Properties	Test Results	As per IS 12269-1987
1	Specific Gravity	3.1	3.10 – 3.15
2	Fineness	4.5	
3	Normal Consistency	33%	30 – 35%
4	Setting Time (in minutes)		
	a) Intial Setting Time	90 min	> 30 Min
	b) Final Setting Time	700 min	< 600 min

5	Compressive Strength of Cement		
	7 days	25 MPa	Not less than 23MPa
	14 days	33.5 MPa	Not less than 33MPa
	28 days	58.8 MPa	Not less than 53MPa

Table II Physical Properties of Silica Fume and GGBS

Sl. No	**Physical properties**		
	Properties	***Silica fume***	***GGBS***
01	Colour	White	Off-white powder
02	PH Value	Maximum 7.5	10-12 (wet condition)
03	Specific surface area	>16000m^2/kg	4189cm^2/g
04	Specific gravity	2.2	2.85-2.95
05	Bulk density	1350-1410 kg/m^3	1200-1300 kg/m^3

III. Methodology

In this article self-compacting concrete with the known percentage of mineral admixtures (GGBS and Silica fumes) are used for replacing ordinary Portland cement to understand the change in properties of SCC. The Ordinary Portland cement is replaced by 10,15,20,25 and 30% of GGBS and for 3 % of silica fume and super plasticizers is also added to get the good workability. Total seven mix designs were prepared and the properties are checked in fresh and hardened state.

The specimen of standard cube of (150mm x 150mm x 150mm) and standard cylinders of diameter 100mm, length 300mm were used to determine the compressive strength and split Tensile strength of concrete. Three specimens were tested for 7 & 28 days with each proportion of GGBS and silica fume replacement. Totally 16 cubes and 16 cylinders were cast for the strength parameters. The constituents were weighed and the materials were mixed by machine mixing. The water binder ratio (W/B) = 0.4 for all the concentration. The specimens were demoulded after 24 hrs, cured in water for 7 & 28 days, and then tested for its compressive and split tensile strength as per Indian Standards.

IV. Results and discussions

Results of fresh and hardened self compacting concrete with partial replacement of GGBS and silica fume are discussed in comparison with those of normal SSC.

From Fig. 1, it is noted that the Cementitious matrix containing GGBS exhibited greater Slump flow due to the increased paste content and increased cohesiveness of the paste. This result was due to the surface characteristics of the GGBS and slag, which created smooth slip planes in the paste. When the GGBS slag is finer than the Portland cement and is substituted on an equal-mass basis, bleeding is reduced; conversely, when the GGBS slag is coarser, the rate and amount of bleeding may decrease. Developed SCC mix passed all key requirements by satisfying all recommended values mentioned in EFNARC guidelines (650 to 800mm). The slump flow test can give an indication as to the consistency, filling ability and workability of SCC. The inverted cone shape restricts flow, and prolonged flow times may give some indications of the susceptibility of the mix to blocking. V-funnel values increases with increase in GGBS as evident from Fig. 2. In case of L-box test results indicated in Fig. 3 and u box tests (as in Fig. 4) , if the concrete flows freely, at rest it will be horizontal, so H_2 / H_1. Therefore the tests values are within the limits as presented in Table III.

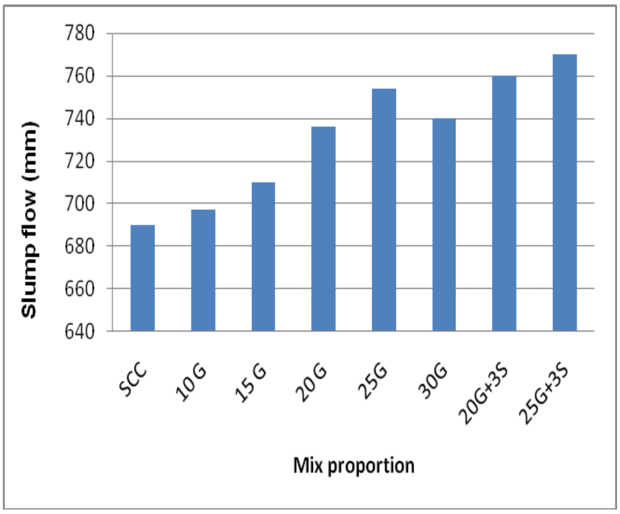

Fig. 1. Variation of Slump Flow

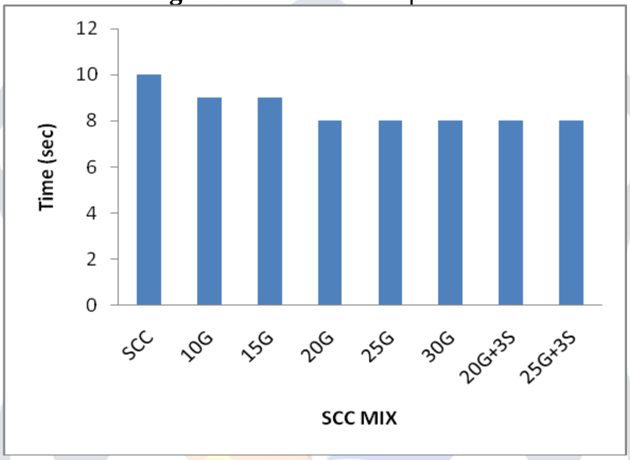

Fig. 2.V-Funnel Test Results

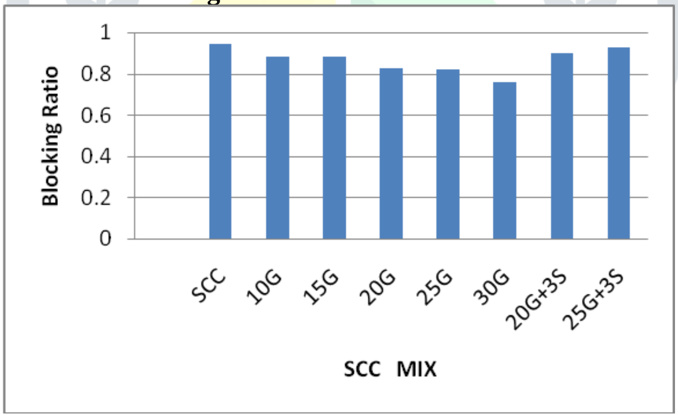

Fig. 3.L-Box Test Results

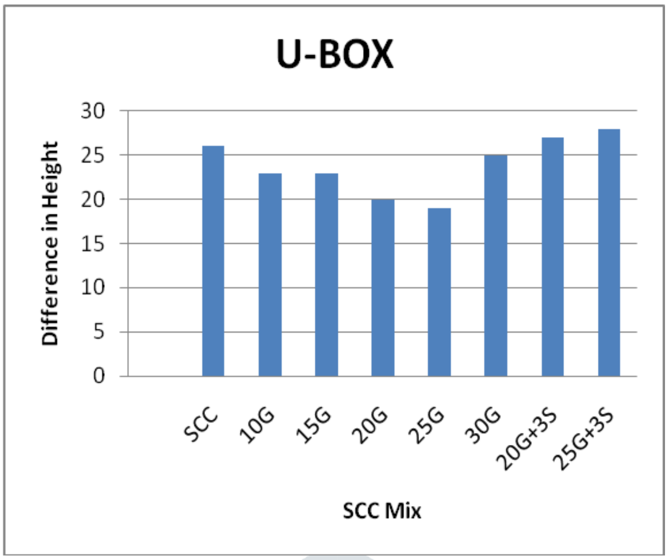

Fig. 4.U-Box Test Results

TABLE I. RESULT S OF FRESH CONCRETE

Mix Name	Proportion	Slump Flow (mm)	V-Funnel Test (sec)	L-box (H2/H1)	U-Box Test (mm)
SCC	Normal SCC	690	10	0.94	26
10G	10% GGBS + SCC	697	9	0.88	23
15G	15% GGBS + SCC	710	9	0.88	23
20G	20% GGBS + SCC	736	8	0.84	20
25G	25% GGBS + SCC	754	8	0.82	19
30G	30% GGBS + SCC	740	8	0.82	25
20G+3S	20% GGBS + 3% SF +SCC	760	8	0.90	27
25G+3S	25% GGBS + 3% SF +SCC	770	8	0.93	28

A. Compressive Strength

The results of compressive strength and split tensile strength were presented in Table IV. The test was carried out conforming to IS 516-1959 to obtain compressive strength of concrete at the age of 7 and 28 days. The cubes were tested using Compression Testing Machine (CTM) of capacity 2000kN. From Fig. 5 it is observed that the compressive strength is 28.59 N/mm^2 and 44.68 N/mm^2 at 7 and 28 days for SCC containing 25% GGBS and 3% silica fume. The maximum compressive strength is observed at 25% replacement of GGBS with 3%silica fume. There is a significant improvement in the compressive strength of concrete because of the high pozzolanic nature of the GGBS and silica fume and its void filling ability.

B. Split Tensile Strength

The results of Split Tensile strength were presented in Table IV. The test was carried out conforming to IS 516-1959 to obtain Split tensile strength of concrete at the age of 7 and 28 days. The cylinders were tested using Compression Testing Machine (CTM) of capacity 2000kN. From Fig. 6 the increase in strength is 3.34N/mm^2 and 4.61N/mm^2 at 7 and 28 days respectively for SSC containing 25% GGBS and 3% silica fume compared to normal SCC. The maximum increase in split tensile strength is observed at 25% replacement of GGBS and 3% silica fume. The optimum silica fume replacement percentages for tensile strengths have been found to be a function of w/cm ratio of the mix.

TABLE II. RESULTS OF COMPRESSIVE AND SPLIT TENSILE STRENGTH

Mix	Compressive Strength (N/mm^2)		Split Tensile Strength (N/mm^2)	
	7 Days	*28 Days*	*7 Days*	*28 Days*
SCC	24.65	40.00	2.42	4.07
10G	24.86	40.12	2.50	4.13
15G	25.24	41.54	2.53	4.21
20G	26.64	42.16	2.67	4.36
25G	27.35	43.20	2.91	4.45

30G	26.31	41.93	2.71	4.41
20G+3S	28.39	43.56	3.20	4.54
25G+3S	28.59	44.68	3.34	4.61

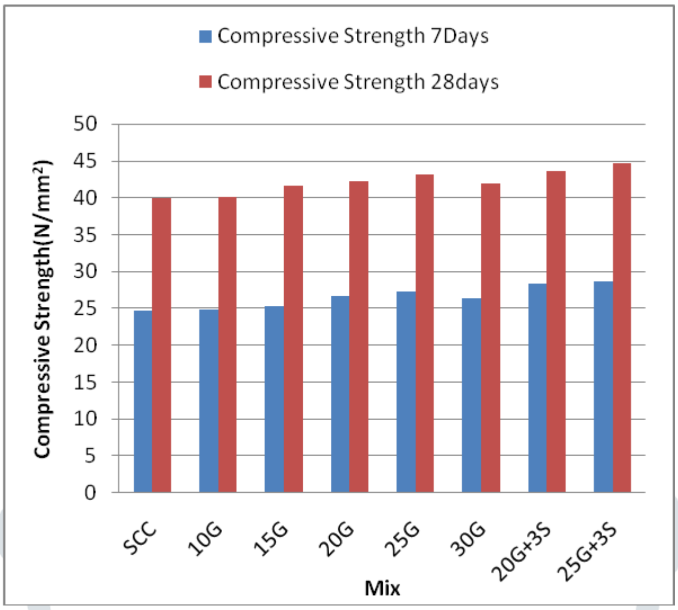

Fig. 5. Compressive strength of SCC at different ages

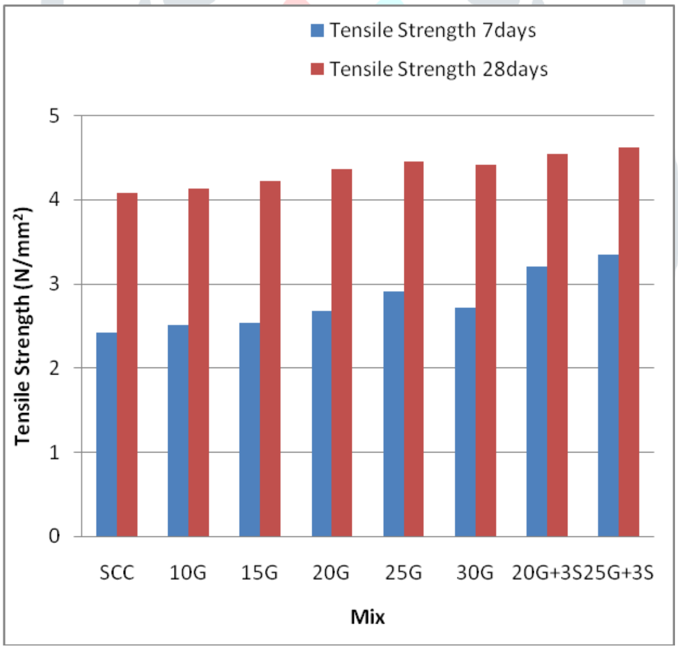

Fig. 6. Split Tensile Strength of SCC at different ages

V. CONCLUSION

Tests conducted on fresh and Hardened properties of SCC mixes based on EFNARC guidelines reveal following conclusions:

- The percentage of GGBS and Silica fumes in the mix will improves the Workability, Mechanical properties of SCC.
- Self compacting concrete using GGBS and Silica Fume have achieved the target strength in all the mixes and also satisfied the fresh state properties required for SCC as per EFNARC specifications.
- As the percentage of finer increases the cement paste volume and workability increases. Density of Concrete is increased which makes it impermeable, well compacted and dense. Hence gives greater strength.
- As the percentage of GGBS increased Slump flow increases. This is because of flakiness and elongated shape of GGBS and also silica fume is denser in appearance.

- Longer curing duration results in higher compressive strength. The compressive strength is more when the specimens were cured for 28 days.
- The Compressive Strength, Split Tensile Strength is Maximum for mix proportion 25% GGBS; Hence SCC has attained sustainability on 25% GGBS mix with 3% of silica fume.

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