FLEXURAL BEHAVOIUR OF SELF COMPACTED CONCRETE BEAMS BY PARTIAL REPLACEMENT OF CEMENT WITH GGBS

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ABSTRACT

Self compacting concrete (SCC) has the property of flowing and compacting due to its own weight. Since compacting of concrete in the presence of grid locked reinforcements are increasing, the need for self flowing concrete is felt very much. Meanwhile Ground Granulated Blast Furnace slag (GGBS) will be an effective alternate to cement which contains cementitious material. In this study, self compacting concretes were considered using GGBS by replacing Portland cement with 10%, 20%, 30%, 40% and 50% by weight. The rheological and mechanical properties of SCG (GGBS incorporated SCC) were found to be increased compared to conventional concrete. Six reinforced concrete beams (SCGB) of shear span to depth ratio (a/d) 2 were tested for flexural capacity and ductile behaviour. The experimental cracking moment of SCGB beams were found to be more than the theoretical cracking moment enhancing its flexural resistance. Also, SCGB beams with higher percentage of GGBS exhibits higher ductility. The outcomes reveal that use of GGBS in SCC enables higher performance with economy and sustainability.

Key words:*Self Compacting Concrete; GGBS; Rheological Property; MechanicalProperty; Flexural Capacity; Ductile Behaviour.*

1. INTRODUCTION

Self compacting concrete (SCC) is defined as a concrete that exhibits a high deformability with good resistance to segregation [1]. The SCC is distinguished by its high fluidity, passing ability and cohesiveness characteristics that eliminate or reduce to a minimum the need for mechanical compaction [2] and has been widely employed to produce structural elements of complex shapes and/or with high density of reinforcement in structures [3]. Since the self-compacting concrete can reach self-leveling work performance in the fresh state by only relying on the action of gravity, there is no need of applying external vibrations in construction sites, which not only improve the quality of concrete placing, but also can greatly save time and labour needed in the construction sites [4]. Hence in the last 15 years, self-compacting concrete has been widely used around the world for its superior constructive ability and higher durability [5].

The production of one ton of Portland cement emits approximately one ton of CO2 into the atmosphere [6]. The use of pozzolans as additives to cement, and more recently to concrete, is well accepted in practice to reduce the use of Portland cement. Ground granulated blast furnace slag (GGBS) is one such pozzolanic material identified by IS456:2000 as a supplementary cementitious material which can be used as a cementitious ingredient in either cement or concrete composites [7].

2. PAST RESEARCH

Ha Thanh Le et al [8] has found that increase in the fineness of rice husk ash content decreased the expansion of mortar due to alkali silica reaction in SCC containing rice husk ash and silica fume. Mohamed I Abukhashaba et al [1] has studied the environmental economic and technical benefits of self compacting fibre reinforced concrete containing cement kiln dust.

The mechanical strength and workability development with the use of cement kiln dust in SCC has been reported. Mostafa Jalal et al [9] presents the effect of silica nano particles, silica fume and class F fly ash as admixtures in high performance self compacting concrete. The use of fly ash improved the rheological property and the use of silica nano particles and silica fume improved the mechanical and transport properties of SCC.

Saifullah I et al [10] has performed experimental investigations on flexural behaviour of under reinforced concrete beams and compared it with analytical results. M K Maroliya [11] has performed a comparative study on flexural behaviour of prestressed concrete beams with reinforced concrete beams. Arivalagan S [12] has dealt with flexural behaviour of reinforced fly ash concrete beams. Oner A et al [13] has carried out experiments to determine the optimum usage of GGBS in concrete to increase the compressive strength. Sonali K Gadpalliwar et al [14] has partially replaced cement with GGBS and reported increase in workability.

In the history of researches related to SCC rise husk ash, silica fume, cement kiln dust, silica nano particles and fly ash were used as admixtures in SCC. The study of rheological, thermal and transport properties has only been reported. But in the current work, GGBS has been employed as a replacement to OPC and along with rheological and mechanical properties, the flexural behaviour of SCC beams were also accounted.

3. MATERIALS USED

3.1. Cement and Aggregates

53 grade Ordinary Portland cement conforming to IS 12269:1987 with specific gravity 3.15 was used. River sand obtained from Chennai and the locally available blue metal crushed stone aggregates of size 20mm were used as fine and coarse aggregates respectively. Their properties like specific gravity, bulk density, percentage of water absorption and fineness modulus were obtained as per IS 2386:1963 and shown in Table 1.

Table 1 Properties of Aggregates

Type	Fine aggregate	Coarse aggregate
Specific gravity	2.67	2.6
Fineness modulus	2.36	4.81
Water absorption (%)	0.5	1.21
Bulk density (kg/m^3)	1628	1562

3.2. Mineral Admixture

Ground Granulated Blast furnace Slag (GGBS), obtained from JSW Cement Limited, Chennai and conforming to IS 12089:1987 was used as the mineral admixture. The physical and chemical properties (as given by the manufacturer) of GGBS used for this study is given in Table 2.

Table 2 Properties of GGBS

Chemical properties

Parameter	**JSW GGBS (%)**	**Codal provisions**
CaO	37.34	----
Al2O3	14.42	----
Fe2O3	1.11	----
SiO2	37.73	----
MgO	8.71	Max. 17%
MnO	0.02	Max. 5.5%
Sulphide sulphur	0.39	Max. 2.0%
Loss on ignition	1.41	----
Insoluble residue	1.59	Max. 5.0%
Glass content (%)	92	Max. 85%
Physical properties		
Description		Value
Fineness of GGBS		13.1%
Specific gravity of GGBS		2.93

3.3. Water

Potable water with pH 7 and as available in KNCET Campus was used.

3.4. Superplasticizer

Ceraplast 300 RS(G) which is sulphonated naphthalene formaldehyde condensates (SNF) type superplasticizer was used to increase the workability of self-compacting concrete at fresh state as reported by the manufacturer and given in Table 3.

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Table 3 Properties of SNF type superplasticizer

Specific gravity (30˚C)	1.235
pH (10% solution)	8.5±0.5
Solid %	43±0.5
Sodium sulphate content	< 4%
Viscosity (30˚C)	20±6

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ISSN 2348 - 7550

MIX DESIGN

The design mix was prepared for M30 grade SCC as per ACI guidelines based on the effect of GGBS as binary blended cement [15]. Based on the strength obtained from trial mix given in Table 4, the actual mix was formulated. The mix type was established by the combination of powder type and Viscosity Modifying Admixture (VMA) type which is prepared by increasing powder content i.e. GGBS and using VMA i.e. superplasticizer. The concrete mix proportions of GGBS incorporated SCC here after designated as SCG were as shown in Table 5. The SCG mixes with 0%, 10%, 20%, 30%, 40% and 50% GGBS were termed as SCG0, SCG10, SCG20, SCG30, SCG40 and SCG50 respectively.

Figure 5 were found to decrease by 0.003%, 2.4%, 4.9%, 5.8%, 7.5% and 27.18%, 30.23%, 35.74%, 14.25%, 16.73% with the replacement of 10%, 20%, 30%, 40%, 50% GGBS to SCC respectively. Bouzoubaa et al [17] has reported that increase in percentage of fly ash decreases the slump flow, the same holds good for GGBS also as shown in Table 6 and Figure 2. It is clearly evident from Table 6 and Figure 3 that the time taken by the SCG mixes to flow through the V- funnel decreases by 1.7%, 0.01%, 1.7%, 0.01% with replacement of 10%, 20%, 30%, 40% GGBS and increases by 0.01% with replacement of 50% GGBS in SCC respectively which is not in good agreement with O.R. Kavitha et al [18] where metakaolin is used as mineral admixturewithout addition of VMA. This may be because of the nature of GGBS to enhance the rheological properties of SCC as specified by M.S.Shetty [19]. Also it is observed from Table 6 and Figure 4 that the blocking ratio was found to increase by 6.3%, 9.96%, 10.98% and decrease by 5%, 5.37% for SCG10, SCG20, SCG30 and SCG40, SCG50 respectively which is in accordance with Navid Ranjbar et al [20].

Table 4 Trial Mix

Designation of mix	Cementitious binder by weight		FA by weight	CA by weight	Water content by weight of cement	Percentage of SP by volume of concrete	Compressive strength at the age of 28 days (N/mm^2)
	OPC	GGBS					
Trial 1	1	0	1.51	1.78	0.35	6	28.64
Trial 2	1	0	1.51	1.78	0.35	4	30.56
Trial 3	1	0	1.51	1.78	0.35	2	36.81

Table 5 Validation of Mix design

Designation of mix	Cementitious binder by weight		FA by weight	CA by weight	Water content by weight of cement	Percentage of SP by volume of concrete
	OPC	GGBS				
SCG0	1	0	1.51	1.78	0.35	2
SCG10	0.9	0.1	1.51	1.78	0.35	2
SCG20	0.8	0.2	1.51	1.78	0.35	2
SCG30	0.7	0.3	1.51	1.78	0.35	2
SCG40	0.6	0.4	1.51	1.78	0.35	2
SCG50	0.5	0.5	1.51	1.78	0.35	2

4. RHEOLOGICAL PROPERTIES

The rheological properties of SCG mixes were found using slump test, V- funnel test, L - box test and U - box test as per EFNARC[16] recommendations and seen through Figure 1.

5. COMPRESSIVE STRENGTH

For getting compressive strength, 150 × 150 × 150 mm cubes were prepared using SCG mixes and tested in a universal testing machine of 2000 kN capacity at the age of 7, 28 and 56 days respectively. The reported strengths were the average of three specimens.

6. RESULTS AND DISCUSSION

6.1. Rheological property

The workability, filling ability and passing ability of SCC was measured by means of slump cone, V funnel and L-box and U-box respectively as shown in Figure 1 and Table 6. The slump diameter and the difference in height obtained from U-Box as shown in Table 6.

Table 6 Fresh Concrete properties

Mix	SCG0	SCG10	SCG20	SCG30	SCG40	SCG50	EFNARC values
Slump flow (mm)	708	706	691	673	667	655	650 - 800
V-funnel test (sec)	11.5	11.3	11.4	11.3	11.4	11.6	6 - 12
L-box (mm)	0.876	0.968	0.973	0.984	0.832	0.829	0.8 - 1
U-box (mm)	5.26	3.83	3.67	3.38	4.51	4.38	0 - 30

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a)

b)

c)

d)

Figure 1.a) Slump flow test **b)** V- Funnel test **c)** L-Box test **d)** U- Box test

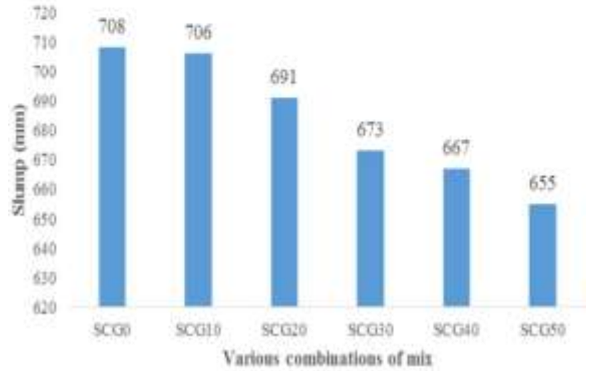

Figure 2 Slump flow of SCG mixes

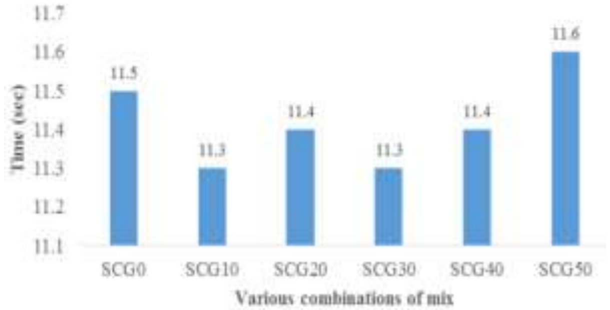

Figure 3 Filling ability of SCG mixes from V- funnel

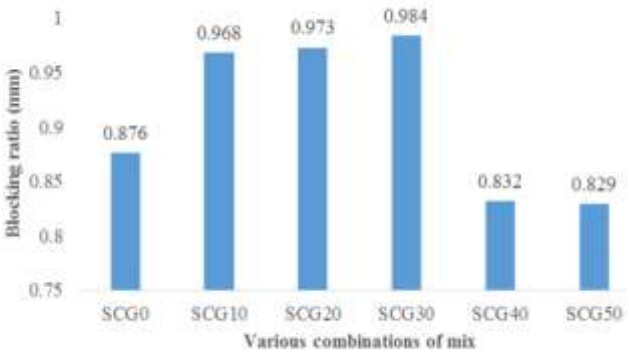

Figure 4. Passing ability of SCG mixes from L – box

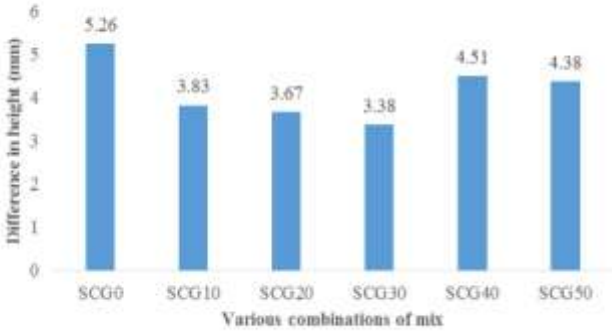

Figure 5 Passing ability of SCG mixes from U – box

6.2. Compressive strength

The mechanical strength of the SCC was determined by conducting compressive strength on SCG cubes at the age of 7, 28 and 56 days. At the age of 7 days, compressive strength of SCG10 and SCG20 were found to drop by 3.99% and 1.45% while compressive strength of SCG30, SCG40 and SCG50 were enhanced by 2.82%, 7.39% and 0.36% respectively from SCG0. It was noticed that the compressive strength of SCG10, SCG20, SCG30, SCG40, SCG50 were declined by 22.38%, 20.21%, 16.52%, 12.17% , 18.83% and improved.

7. CONCLUSION

❖ The use of GGBS as partial replacement for OPC in SCC not only reduces the emission of CO2 from OPC but also enhances the mechanical and rheological properties of SCC.

❖ The workability of SCC found by slump decreases with increase in percentage of GGBS, the time of flow through the V- funnel test time decreased with addition of GGBS in SCC and the blocking ratio obtained from L- box was found to be satisfactory up to 30% replacement of OPC with GGBS in SCC.

- At the age of 7 days, the compressive strength of SCG10 and SCG20 were found to drop by 5.58% and 18.91% while compressive strength of SCG30, SCG40 and SCG50 were enhanced by 4.02%, 10.17% and 0.01% respectively from conventional mix.
- It was noticed that the compressive strength of SCG10, SCG20, SCG30, SCG40, SCG50 were reduced by 28.85%, 26.05%, 21.29%, 15.68% , 24.26% and improved by 3.39%, 3.89%, 5.67%, 8.79%, 6.25% at the age of 28 and 56 days respectively from conventional mix.
- SCGB beams with higher percentage of GGBS exhibits higher ductility.
- The experimental cracking moment of SCGB0, SCGB10, SCGB20, SCGB30, SCGB40 and SCGB50 is 54.46%, 65.21%, 60%, 64.78%, 61.78% and 59.64% more than the theoretical cracking moment. This exposits that the replacement of GGBS to OPC in SCC enhances the flexural behaviour of self compacting concrete beams.

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- Ductility factor of SCGB10, SCGB20, SCGB30 were 19%, 20.2%, 17.78% higher than conventional concrete where as SCGB40 and SCGB50 were 1.25% and 3.45% lesser than conventional concrete mix. Hence, it can be concluded that upto 30% replacement of GGBS to OPC in SCC is effective.