ISSN: 2277-3754
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 1, Issue 4, April 2012

# Flexural Behavior of Reinforced Self Compacting Concrete Containing GGBFS

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*Abstract*— ***The main objective of this study was to investigate the flexural behaviour of self compacting Concrete (SCC) beams using GGBFS as mineral admixtures along with the addition Super plasticizer. Experimental based analysis has been widely used as a means to find out the response of individual elements of structure. In the present study, destructive test on simply supported beam measuring 100 X 100 X 2000 mm and reinforced with HYSD bars was performed in the laboratory & load-deflection data of that SCC reinforced concrete beams was recorded. Preliminary experimental investigation was done to study the influence of GGBFS on fresh and hardened properties of SCC. an analytical and experimental investigation was carried out for a beam With different mixes incorporated various doses of GGBFS (0%, 30%, 40% and 50%) as partial replacement of cement with a water-binder ratio of 0.35 and 0.40 is adopted. To improve the workability of concrete, super plasticizer of 2.2% by weight of cement is added.***

*Index Terms*— **Beams, Flexural Behavior, GGBFS, Self Compacting Concrete.**

## I. INTRODUCTION

Concrete structural components exist in buildings and bridges in different forms. Understanding the response of these components during loading is crucial to the development of an overall efficient and safe structure. Different methods have been utilized to study the response of structural components. Experimental based testing has been widely used as a means to analyze individual elements and the effects of concrete strength under loading. Creation of durable concrete structure requires adequate compaction by skilled laborers. The gradual reduction of skilled workers in construction industry has led to a similar reduction in the quality of construction work. One solution for the achievement of durable concrete structures independent of the quality of construction is the employment of Self Compacting Concrete (SCC). SCC can be considered as a concrete that is able to flow under its own weight and completely fill the formwork, even in the presence of dense reinforcement, without the need of vibration [1]. It is now widely used for highly congested reinforced concrete structures in seismic region. Heavy reinforcement restricts the access of vibrators that are required for adequate consolidation of Normal Concrete (NC). Moreover, excessive vibration can cause undesirable segregation and bleeding. The invention of Super plasticizers (SP), Viscosity Modifying Agents and mineral admixtures made it possible to cast concrete of high fluidity and good cohesiveness. SCC has little resistance to flow and possesses enough viscosity to be handled without segregation or bleeding. The hardened SCC is dense, homogeneous and has the same engineering properties and durability as traditionally vibrated concrete. SCC is more brittle than NC under loading [2]. Ductile design of reinforced concrete beams is generally related to flexural failure in bending, but very often the presence of high shear force reduces their flexural capacity. Many studies have been conducted to investigate the combined flexural and shear behavior of fiber reinforced concrete beams [3, 4, 5].

The usage of self-compacting concrete in ready mix concrete plants has tremendously increased due to its advantages in consolidation, uniformity and reliability. Self-compacting concrete (SCC) is an innovative concrete that does not require any vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. SCC is a complex system that is usually proportioned with one or more additions and one or more chemical admixtures. Successful self-compacting concrete must have high fluidity (for flow under self-weight), high segregation resistance (to maintain uniformity during flow) and sufficient passing ability so that it can flow through and around reinforcement without blocking or segregating [6, 7]. Super plasticizers added to concrete provide a better workability. One of the disadvantages of SCC is its cost, associated with the use of chemical admixtures and use of high volumes of Portland cement. The water demand and workability are controlled by particle shape, particle size distribution, particle packing effects and the smoothness of the surface texture [8]. One alternative to reduce the cost of SCC is the use of additions. Due to the better engineering and performance properties, additions such as Ground Granulated Blast-Furnace Slag (GGBFS) are normally included in the production of high-strength and high-performance concrete [9].

The objectives of this study are to develop a SCC mix with GGBFS, to study the fresh and hardened properties of SCC with and without GGBFS, to study the influence of GGBFS on flexural behavior of SCC beam specimens and this paper was to investigate and evaluate the reinforced concrete beam behavior at first cracking, behavior beyond first Cracking and load-deformation response at different mix ratio.

## II. PRILIMINARY EXPREMENTAL INVESTIGATION

### *A. Materials:*

Ordinary Portland cement of grade 43 conforming to IS: 12269-1987 was used. Locally available river sand

ISSN: 2277-3754
International Journal of Engineering and Innovative Technology (IJEIT)
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conforming to grading zone II of IS: 383-1970 was used and crushed stones of nominal size 12.5mm conforming to IS 383-1970 was used. The specific gravity of coarse aggregate was 2.77. The maximum size of the coarse aggregate was restricted to avoid the blocking effect in SCC. The amount of coarse aggregates in SCC mixtures is much lower than in traditional vibrated concrete. On the other hand, they contain a high amount of fine fillers and/or additives to increase the viscosity. In this way, the stability of the mix is maintained, bleeding is reduced, and separation of coarser aggregates is avoided [10]. The specific gravity of cement and sand was 3.15 and 2.65 respectively. Besides this the byproducts, slag cement from Agni steel plant, erode. In general, the approach of minimizing free water content to enhance stability can result in SCC mixtures with a low yield stress and moderate-to-high viscosity levels. The low water content requires a relatively high dosage of high range water reducers to obtain the required deformability especially with the lower binder contents [11]. A new generation based polycarboxylic ether (PCE) was used. In terms of effectiveness PCE is higher compared to other bases and it also works at low dosages than other types of super plasticizers. The pH of super plasticizer was greater than 6. The characteristic properties and mineralogical composition of these three mineral admixtures and the cement are given in Table1.

TABLE 1: PROPERTIES OF PORTLAND CEMENT AND MINERAL ADMIXTURES

| Component (%) | Cement | Slag cement |
|---|---|---|
| $SiO_2$ | 20 | 10-19 |
| (MgO) | 2.5 | 11 |
| $Al_2O_3$ | 4.85 | 1-3 |
| (LOI) | 2.0 | 1.2 |
| $Fe_2O_3$ | 0.6 | 22-30 |
| (CaO) | 62.56 | 40-52 |

### *B .Mix Proportions*

Okumara's method [2], based on EFNARC specifications [12], was used for this study. Trials were done by varying the amount of coarse aggregate, water/binder ratio and GGBFS. Finally coarse aggregate and fine aggregate are fixed as 900 and 600 kg/m$^3$ and 30MPa SCC mix was obtained after several trials as shown in Table 2.

## III. INFLUENCE OF GGBFS ON FRESH AND HARDENED PROPERTIES OF SCC

30%, 40% and50 % GGBFS were added to SCC mix and checked for the fresh properties. The water and S.P was added and the mixing continued. After the completion of mixing, standard tests for SCC suggested by EFNARC [12] were done, which is given in Table 3. Test results of fresh properties are shown in Table 4.

**Table 2. Mixture Proportions For Scc (Kg/m$^3$)**

| Materials | Cement | GGBFS | W/P | SP |
|---|---|---|---|---|
| M1 | 500 | - | 0.35 | 3.5 % |
| M2 | 350 | 150 | 0.35 | 2.2 % |
| M3 | 300 | 200 | 0.35 | 2.17 % |
| M4 | 250 | 250 | 0.35 | 2% |
| M5 | 500 | - | 0.4 | 3.3 % |
| M6 | 350 | 150 | 0.4 | 2.14 % |
| M7 | 300 | 200 | 0.4 | 2.12 % |
| M8 | 250 | 250 | 0.4 | 2% |

TABLE 3. LIMITATIONS SPECIFIED BY EFNARC

| est methods | Units | Minimum | Maximum |
|---|---|---|---|
| Slump flow | mm | 650 | 800 |
| T50 | sec | 0 | 5 |
| L box | $h_2/h_1$ | 0.8 | 1 |
| V funnel | sec | 0 | 3 |
| U box | $h_2$-$h_1$ | 0 | 30 |

TABLE4.FRESH PROPERTIES OF SCC MIXES

| Mixture no | Slump (mm) | V-funnel (Sec) | U-Box ($h_2$-$h_1$) mm | L-Box ($h_2/h_1$) | $T_{50}$ (Sec) |
|---|---|---|---|---|---|
| M1 | 620 | 12 | 23 | 0.9 | 7 |
| M2 | 680 | 10 | 26 | 0.9 | 5 |
| M3 | 685 | 8 | 25 | 0.95 | 5.5 |
| M4 | 690 | 7 | 24 | 1 | 6 |
| M5 | 635 | 11 | 22 | 0.9 | 8 |
| M6 | 685 | 10 | 25 | 0.95 | 6 |
| M7 | 690 | 9 | 23 | 1 | 5.5 |
| M8 | 695 | 8 | 22 | 1 | 5 |

For all the mixtures, at constant water/powder ratio and varying percentage of super plasticizer content, an increase in slump flow was observed up to 50% of slag content with an optimum at 30%, and with super plasticizer dosage at 2.2%. V funnel test was performed to assess the flowabilty and

ISSN: 2277-3754
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 1, Issue 4, April 2012

stability of the SCC. Hence the value obtained from the experimental investigation is within the limit of EFNARC. The increase in coarse aggregate causes the increase in V-Funnel. The increase in water results in reduction in flow time. L-box ratio indicates the filling and passing ability of each mixture. L-box test is more sensitive to blocking. There is a risk of blocking of the mixture when the L-box blocking ratio is below 0.8. The obtained L-box values are tabulated in Table 4

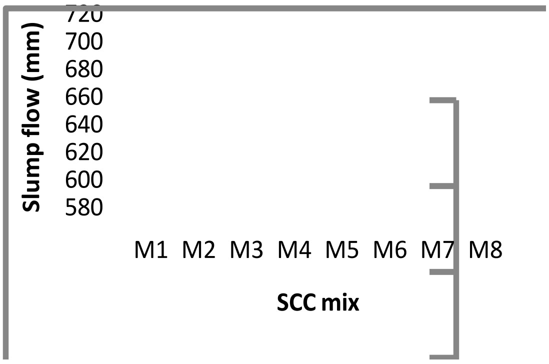


**Fig. 1 Slump flow of SCC with GGBFS**

All the specimens were cured by ponding for 28 days. The influences of GGBFS are shown in Fig. 2, 3, 4. It was observed that, GGBFS addition improve all the hardened properties of SCC.

**TABLE 5. COMPRESSIVE STRENGTH OF GGBFS CONCRETE MIXES**

| Compressive Strength MPa | | |
|---|---|---|
| GGBFS | | |
| Mixture no | 7days | 28 days |
| M1 | 20 | 30 |
| M2 | 24.1 | 32.44 |
| M3 | 21.4 | 31.8 |
| M4 | 18.2 | 31.55 |
| M5 | 22 | 32 |
| M6 | 23.2 | 31.5 |
| M7 | 22.5 | 33 |
| M8 | 19 | 34.7 |

**TABLE 6. SPLIT TENSILE STRENGTH OF GGBFS CONCRETE MIXES**

| Split Tensile Strength MPa | | |
|---|---|---|
| GGBFS | | |
| Mixture no | 7days | 28 days |
| M1 | 1.08 | 1.74 |
| M2 | 1.14 | 1.89 |
| M3 | 1.15 | 2.01 |
| M4 | 1.16 | 2.09 |
| M5 | 1.12 | 1.82 |
| M6 | 1.16 | 1.87 |
| M7 | 1.19 | 2.12 |
| M8 | 1.23 | 2.34 |

**TABLE 7. FLEXURAL STRENGTH OF GGBFS CONCRETE MIXES**

| Flexural Strength MPa | | |
|---|---|---|
| GGBFS | | |
| Mixture no | 7days | 28 days |
| M1 | 2.14 | 3 |
| M2 | 2.24 | 3.2 |
| M3 | 2.8 | 3.3 |
| M4 | 3.12 | 3.44 |
| M5 | 2.23 | 3.13 |
| M6 | 2.26 | 3.32 |
| M7 | 2.67 | 3.4 |
| M8 | 3.23 | 3.56 |

The compressive, split and flexure studies at different ages are shown in the figures (2, 3, 4). When compared to that of the control mixture increasing amounts of mineral admixtures generally decrease the strength. Thus it is clear that the roles of GGBFS are also better understood that they only act as mineral admixtures reducing the compressive strength of GGBFS series. At the early stage, pozzolanic reactions of GGBFS were not sufficient to increase compressive strength. But at 28 days the slower pozzolanic reactions played a part in the GGBSF mix and it has the highest compressive strength results. In the case of GGBFS, filling of the voids between the larger cement particles, and increasing production of secondary hydrates by pozzolanic reactions with the lime resulting from the primary hydration enhances compressive strength [13]. Furthermore, it chemically reacts with the calcium hydroxide produced by the hydration of the Portland cement (PC) to form calcium silicate hydrates (C-S-H) which binds the concrete together.

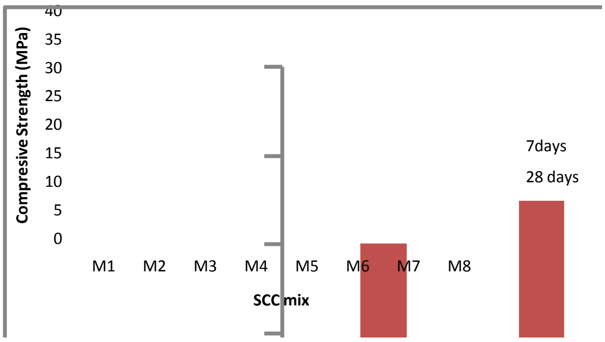


**Fig. 2 SCC Mix Vs Compressive Strength**

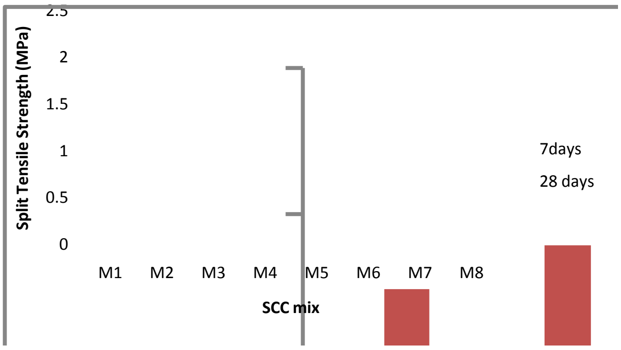


**Fig. 3 SCC Mix Vs Split Tensile Strength**

ISSN: 2277-3754
International Journal of Engineering and Innovative Technology (IJEIT)
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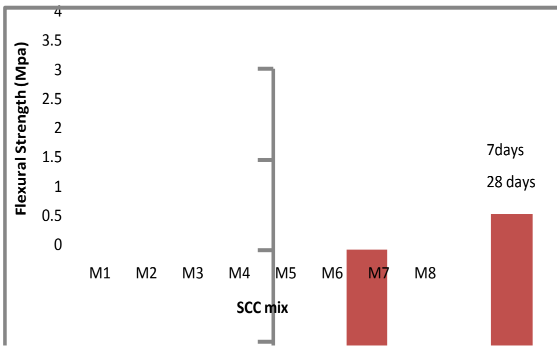


Fig. 4 SCC Mix Vs Flexural Strength

## IV. EXPREMENTAL INVESTIGATION ON SCC BEAM

Experimental studies were conducted on SCC control beams and fibre reinforced beams. The role of GGBFS on the ultimate, first crack load and load deflection of SCC beams were studied. The beams were of size 100x100x2000mm. The reinforcement details of the beams are shown in Fig. 5. The reinforcements were provided based on the provisions of IS code [14].

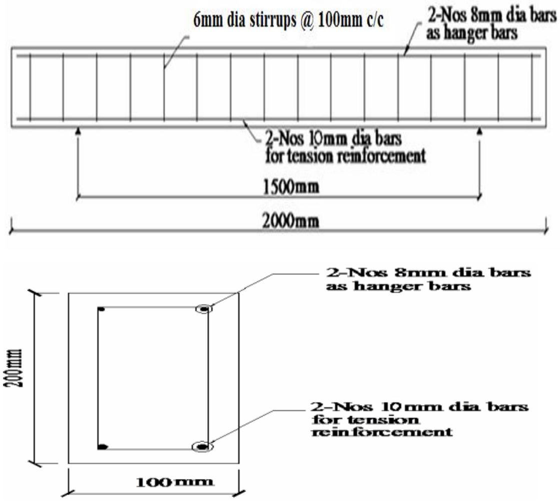


Fig 5 Flexure Beam Detailing

Casting moulds of beam specimens were oiled and was properly aligned to exact dimension on the concrete platform. Reinforcement cage was placed inside the mould to maintain proper cover. After ensuring all the fresh properties, the mix was poured into the wooden mould. After filling the mould, the concrete surface was levelled and finished using a trowel. After 24 hrs of casting, wet gunny bags were spread over the concrete specimens and kept without disturbance until it attains a hardened state. After the removal of moulds, beams and cubes were put for 28 days curing. Usual checks were done in order to assure proper curing of specimens. To study the influence of GGBFS on flexural behavior, % of GGBFS were varied by 30,40 and 50% The beams were subjected to two-point loading under simply supported end condition. The loading was given using a hydraulic jack of 50T capacity.

TABLE8

TABLE 8. TEST RESULTS FOR FLEXURE BEAM

| Beam | % GGBFS | W/C Ratio | First Crack Load (kN) | Ultimate Load (kN) | Deflection at Ultimate Load (mm) |
|---|---|---|---|---|---|
| M1 | 0 | 0.35 | 18 | 35 | 8.12 |
| M2 | 150 | 0.35 | 22 | 47 | 9.23 |
| M3 | 200 | 0.35 | 21 | 44 | 8.66 |
| M4 | 250 | 0.35 | 18 | 36 | 8.3 |
| M5 | 0 | 0.4 | 20 | 60 | 11.22 |
| M6 | 150 | 0.4 | 25 | 74 | 14.34 |
| M7 | 200 | 0.4 | 22 | 69 | 13.12 |
| M8 | 250 | 0.4 | 19 | 65 | 12.92 |

All the beams were tested with an overall span of 2m. A load cell of 50T capacity with a least count of 0.1T (0.981kN) was used to measure the applied load. The test set-up is shown in Fig 6.

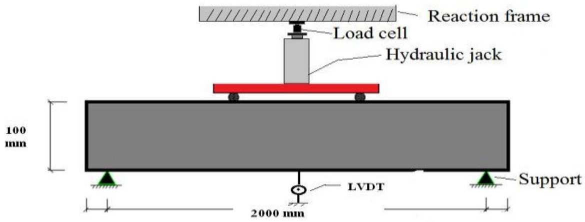


Fig 6. Schematic diagram of test set-up

The parameters recorded were first crack load, mid-span deflection, ultimate load and mode of failure. Mid-span deflection was noted using LVDT (Linear variable differential transducer) for all 0.5T increment of load. The load vs. deflection plots are shown in Fig. 7 & 8. The test results of all the beams are shown in Table 8. The results are compared with control specimen as shown in Fig 9 & 10.

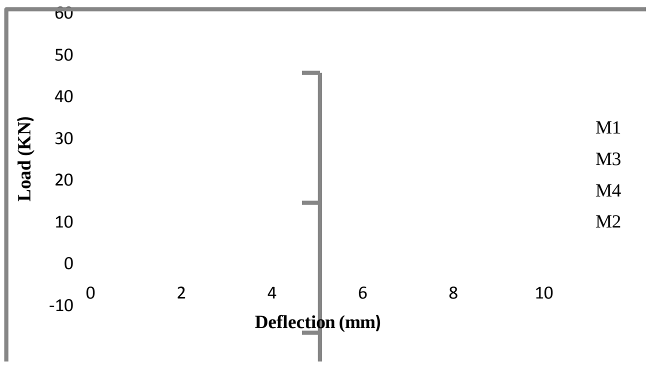


Fig 7 Comparison of Load-Deflection Behavior of 0.35 w/c ratio SCC Beams with Conventional Beam

ISSN: 2277-3754
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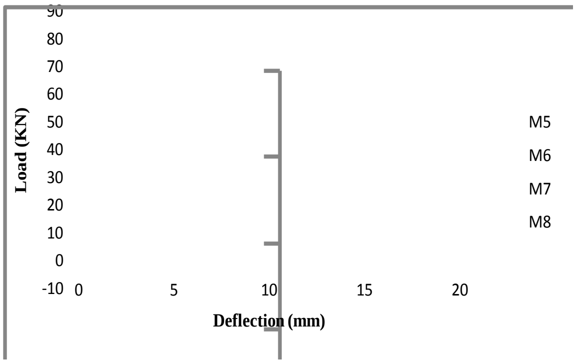


**Fig 8 Comparison of Load-Deflection Behavior of 0.40 w/c ratio SCC Beams with Conventional Beam**

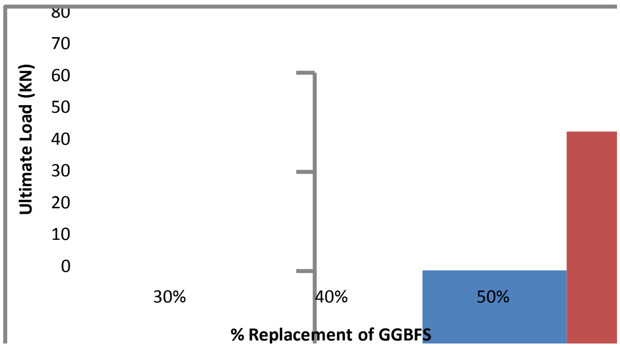


**Fig 9 Comparison of Ultimate Load and % of 0.40 w/c ratio GGBFS Replaced for SCC Beams with Conventional Beam**

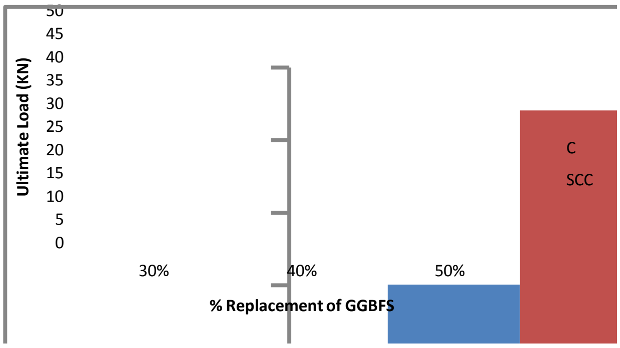


**Fig 10 Comparison of Ultimate Load and % of 0.35 w/c ratio GGBFS Replaced for SCC Beams with Conventional Beam**

It was observed that the first crack loads and ultimate loads were increasing with increase in GGBFS. Major influence was shown by beam with 40% GGBFS.

## V. CONCLUSION

The tests were performed to determined the Flexural behavior of SCC mixtures and the results of the tests are as follows

- All the SCC mixes had a satisfactory performance in the fresh state. Among the mineral admixtures considered, the GGBFS 30% series had a good workability properties compared to other GGBFS series.
- In general the use of mineral admixtures improved the performance of SCC in fresh state and also avoided the use of VMAs.
- Optimum W/P ratio was chosen as 0.35 by weight, the ratio greatly beyond or less than this may cause segregation and blocking tendency in SCC mixture.
- Compared to control beam, increase in First crack load was observed for beams with 30% and 40 % GGBFS respectively.
- In general, beam with 40% GGBFS have shown better performance compared to other beam.

## ACKNOWLEDGMENT

I thank the almighty god giving me the opportunity, strength and determination to enhance myself. I whole heartedly thank Dr. R.Venkatasubramani Head of the Department – Civil Engineering, for his essential support, guidance and his encouragement for this project work. I am grateful to my guide Dr. P.MuthuPriya - Associate Professor, Civil Engineering. for her full support and guidance. I thank the department , faculty members, and non-teaching staffs for their help.

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