**American Journal of Engineering Research (AJER)**
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-03, Issue-01, pp-119-127
www.ajer.org

Research Paper Open Access

# Flexural Behaviour of Reinforced Concrete Beams with Partial Replacement of GGBS

S.P.Sangeetha[#1], P.S Joanna[#2]
[#1](*Research Scholar, Civil Engineering Department, Hindustan University, Chennai, India)*
[#2] *(Professor, Civil Engineering Department, Hindustan University, Chennai, India)*

***Abstract:* -** The present study focuses on the structural behavior of reinforced concrete beam with Ground Granulated Blast furnace Slag (GGBS).It is an inexpensive replacement of Ordinary Portland Cement (OPC) used in concrete, and it improves fresh and hardened properties of concrete. Experimental investigation included testing of eight reinforced concrete beams with and without GGBS. Portland cement was replaced with 40% GGBS and Glenium B-233 was used as superplastisizer for the casting of beams. The results of laboratory investigation on the structural behavior of reinforced concrete beams with GGBS are presented. Data presented include the load-deflection characteristics, cracking behavior, strain characteristics and moment- curvature of the reinforced concrete beams with and without GGBS when tested at 28 days and 56 days. The investigation revealed that the flexural behaviour of reinforced GGBS concrete beams is comparable to that of reinforced concrete beams.

***Keywords:* -** *Ordinary Portland cement, Ground Granulated Blast furnace Slag, Reinforced concrete beams, moment- curvature*

## I. INTRODUCTION

GGBS concrete is a type of concrete in which a part of cement is replaced by ground granulated blast furnace slag, which is an industrial waste. As a result of its low environmental impacts, using GGBS can reduce significantly many of the environmental burdens associated with concrete. If concrete is mixed with ground granulated blast furnace slag as a partial replacement for Portland cement, it would provide environmental and economic benefits and the required workability, durability and strength necessary for the structures. The cementitious efficiency of ground granulated blast furnace slag (GGBS) at 28 days was tested in concrete at various replacement levels and concluded that it is possible to design GGBS concrete for a desired strength upto an optimum replacement percentage of 50% [1].The characteristics of $M_{30}$ concrete with partial replacement of cement with GGBS was studied and it was found that the partial replacement of cement with GGBS improves the strength of the concrete substantially compared to normal concrete[2]. The behavior of concrete with GGBS at different curing period was tested and found that its strength at early ages is less but continues to gain strength over a long period [3].Experimental studies on the geometric characteristics of concrete with 50% replacement of GGBS proved that the strength of concrete with GGBS increased with age[4]. Studies on the effect of using GGBS as partial replacement in producing a engineered cementitious composites, a ductile cementitious composite reinforced with steel fibers and experimentally proved that addition of slag not only increased the strength of concrete but also increased the binding property of steel[5].The stress strain behavior of concrete made with different cementitious admixtures like GGBS, flyash was experimented and found that the addition of these mineral admixtures reduces the strain in reinforced concrete[6]. Extensive research has been done on the compressive strength and durability of GGBS concrete. Not many investigations were reported on the flexural behavior of concrete beams with GGBS. This paper presents the behavior of reinforced concrete beams with 40% GGBS at 28 and 56 days curing. Data presented include the load-deflection characteristics, cracking behavior, strain characteristics and moment- curvature of the reinforced concrete beams with and without GGBS when tested at 28 days and 56 days.

## II. EXPERIMENTAL INVESTIGATION

### *2.1 Materials*

The materials used in the mix design were Ordinary Portland Cement (OPC), river sand, GGBS and potable water. Beam specimens were made with $M_{30}$ grade concrete Water binder ratio of 0.45 and 0.4% of Glenium B233 superplasticiser was used to impart better workability. Fe 500 grade steel was used for longitudinal reinforcement and for stirrups**.**

### *2.2 Preliminary Investigation*

To optimize the percentage replacement of cement with GGBS, preliminary Investigations on were conducted on cube specimens of 150 mm size with 0%,30%, 40% ,50% and 60% GGBS. The specimens were tested at 28 and 56 days in a compression testing machine of capacity 100 T. Compressive strength of concrete with GGBS was less than the ordinary concrete specimens when tested at 28 days, but after 28 days the concrete specimens with 30% and 40% was more than the ordinary concrete specimens when tested at 56 days. Beyond 40% there was gradual decrease in the compressive strength of concrete. Hence beam specimens were casted with 40% GGBS.

### *2.3 Test specimen details*

Eight numbers of reinforced concrete beams with and without GGBS were cast and tested. The span of the beam was 2500 mm and of size 150 mm x 250 mm**.** Out of the 8 specimens tested, four specimens were cast without GGBS and four specimens were cast with 40% GGBS as replacement for cement. Four specimens were tested at 28$^{th}$ day and four specimens were tested at 56$^{th}$ day from the date of casting. Reinforcement details of the specimens tested are given in Table I. A five lettered designation is given to the specimens. First 2 letters represents the type of beam (Controlled and GGBS beams), 3rd one % of GGBS, 4th one identity of specimen in a particular series as two specimens were tested in each series and the last one indicates the day on which the specimen is being tested.

**TABLE I Test beam details**

| S.No | Specification | Testing of Beams (Days) | Reinforcement in Beams | | | |
|---|---|---|---|---|---|---|
| | | | Longitudinal | | Stirrups (mm) | |
| | | | Top | Bottom | Diameter | Spacing |
| 1 | CB0% 1-28 | 28 | 2#10 | 3#12 | 8 | 160 |
| 2 | CB0% 2-28 | | 2#10 | 3#12 | 8 | 160 |
| 3 | GB40%1-28 | | 2#10 | 3#12 | 8 | 160 |
| 4 | GB40%2-28 | | 2#10 | 3#12 | 8 | 160 |
| 5 | CB0% 1- 56 | 56 | 2#10 | 3#12 | 8 | 160 |
| 6 | CB0% 2- 56 | | 2#10 | 3#12 | 8 | 160 |
| 7 | GB40%2-56 | | 2#10 | 3#12 | 8 | 160 |
| 8 | GB40%2-56 | | 2#10 | 3#12 | 8 | 160 |

### *2.4 Test set-up*

The testing was carried out in a loading frame of 40T capacity. All the specimens were white washed in order to facilitate marking of cracks. Strain gauges of 20 mm were fixed to the reinforcement to measure the strain and LVDTs were used for measuring deflections at several locations one at midspan, two directly below the loading points and two near the end supports as shown in Figure 1.Strain gauges and LVDTs were connected to a data logger from which the readings were captured by a computer at every load interval until failure of the beam occurred. The beams were subjected to two-point loads under a load control mode. The development of cracks was observed and the crack widths were measured using a hand-held microscope with an optical magnification of X50 and a sensitivity of 0.02 mm. Figure 2(a) and 2(b) shows the arrangement of LVDT and Strain gauges in the experimental setup.

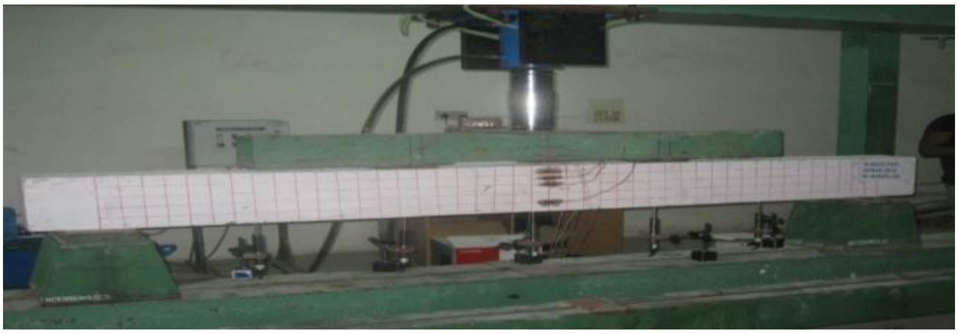


Fig.1 Experimental set-up for the test specimens

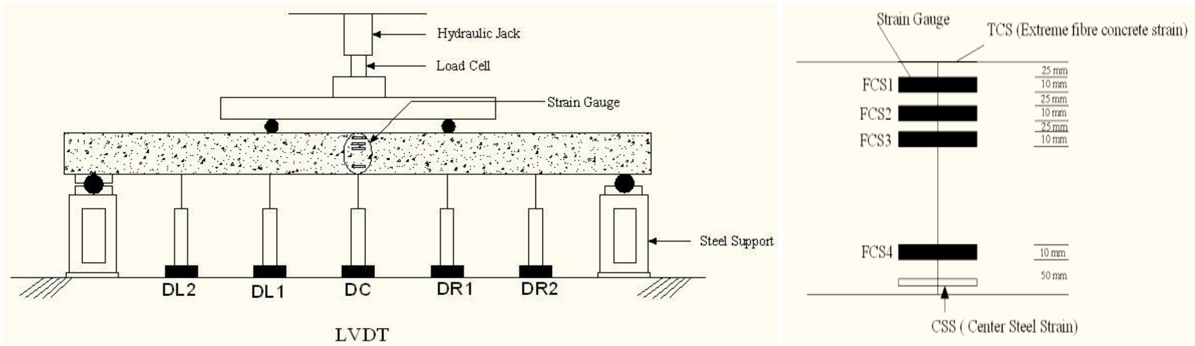



Fig 2: Position of LVDT's and Position of Strain gauges

## III. RESULTS AND DISCUSSION

### *3.1 General observations*

Vertical flexural cracks were observed in the constant-moment region and final failure occurred due to crushing of the compression concrete with significant amount of ultimate deflection. When the maximum load was reached, the concrete cover on the compression zone started to fall for the beams with and without GGBS. Figure 3 shows the failure pattern of the test specimens. Crack formations were marked on the beam at every load interval at the tension steel level. It was noticed that the first crack always appears close to the mid span of the beam. The crack widths at service loads for GGBS concrete beams ranged between 0.16mm to 0.2mm

Fig. 3: Failure Pattern of the beams with 40% GGBS

### *3.2 Load-deflection curve*

The experimental load-deflection curves of the RC beams with 0% and 40% GGBS when tested at 28th day and 56th day are shown in Figure 4 & 5 respectively. The average ultimate loads for controlled beams and 40% GGBS concrete beams are 144 kN and 135 kN respectively at 28$^{th}$ day and it is 164 kN and 178kN at 56$^{th}$ day. Though the ultimate loads for the Beams with 40% GGBS is less than that of the controlled beams at 28$^{th}$ day, its ultimate load increases at 56$^{th}$ day.

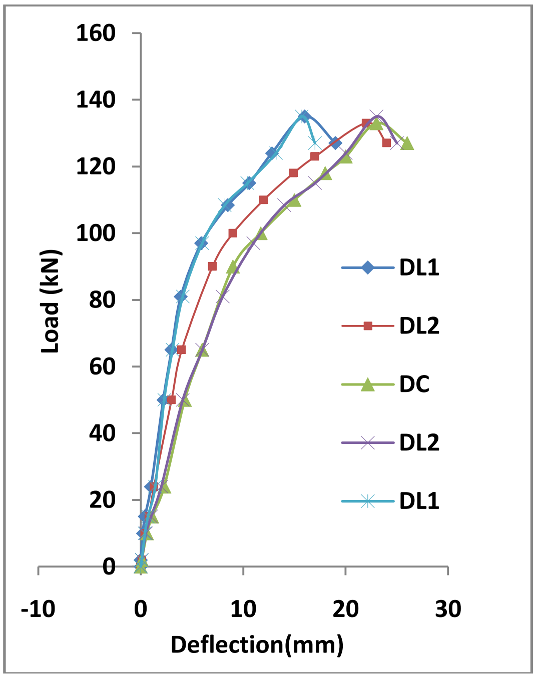



Fig. 4.(a) CB 0% 1-28

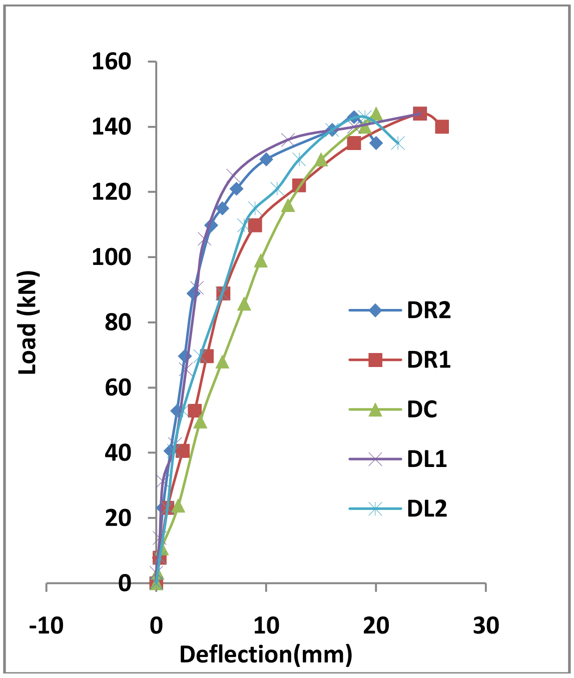



Fig.4. (b) CB 0% 2-28

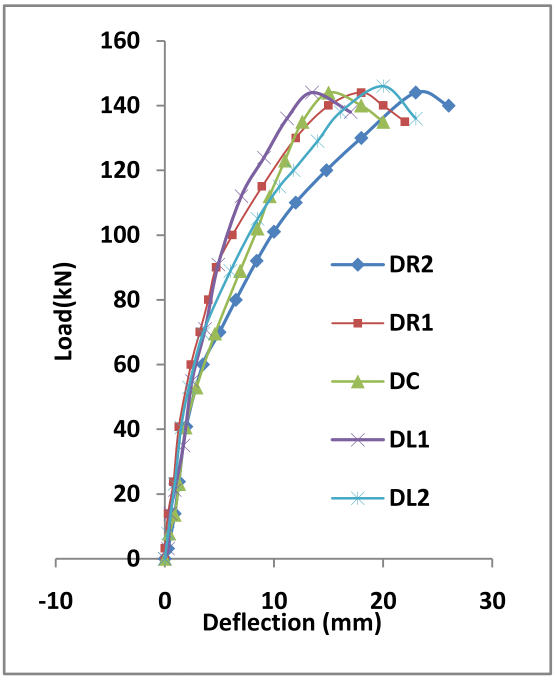



Fig.4. (c) GB 40% 1- 28

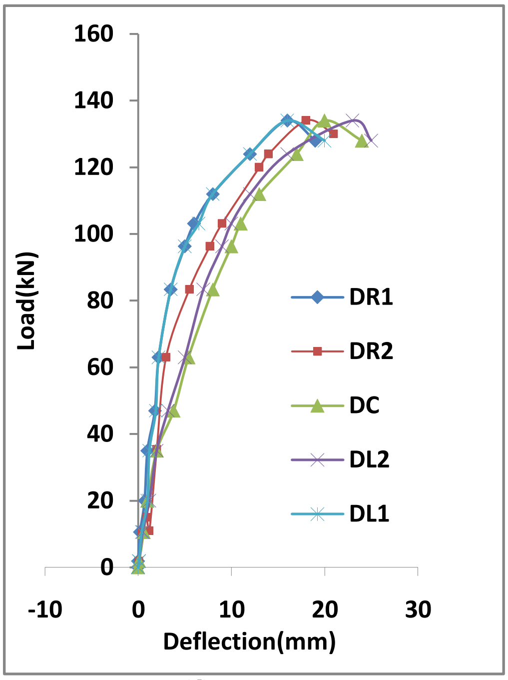



Fig. (d) GB40% 2- 28

Fig 4: Load- Deflection curves for the beams tested at 28 days

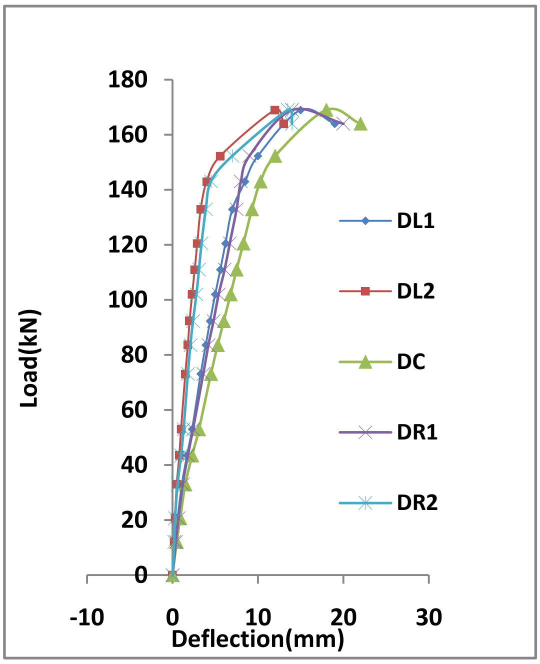



Fig.5 (a) CB0% 1-56

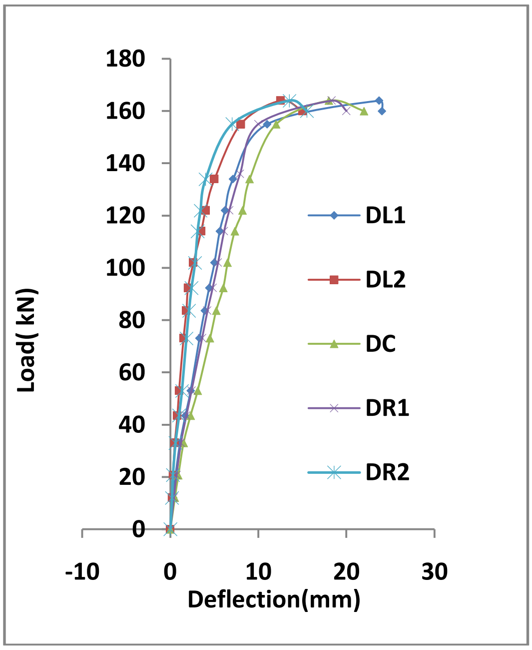



Fig.5. (b) CB0% 2-56

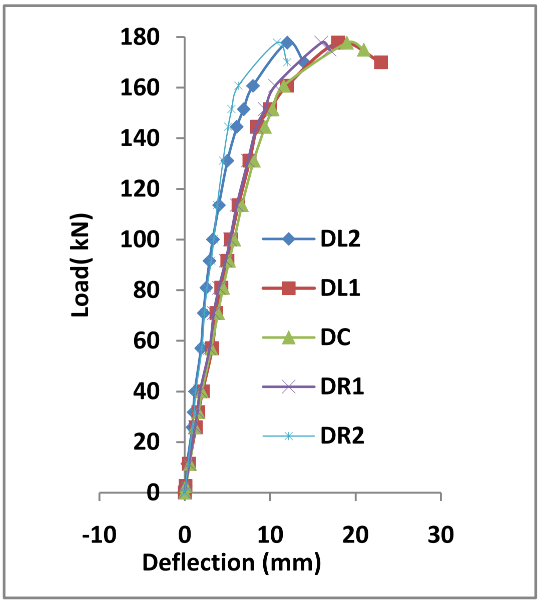



Fig.5 (c) GB 40% 1- 56

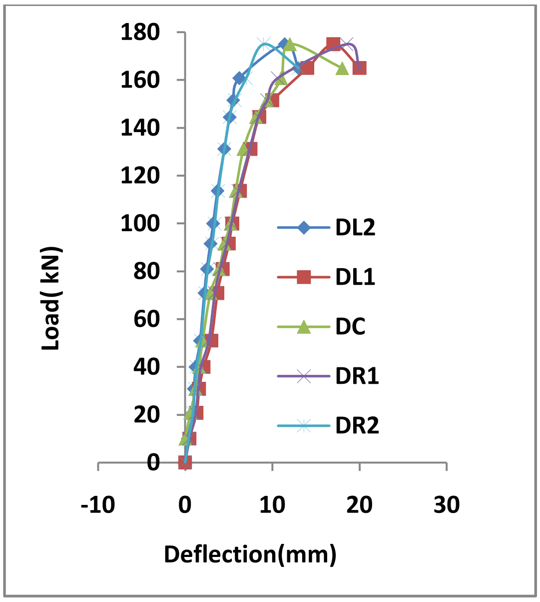



Fig.5. (d) GB 40% 2- 56

Fig. 5: Load- Deflection curves for the beams tested at 56 days

***3.3 Concrete and Steel Strain***

The concrete and steel strains measured at every load increments at $28^{th}$ day and $56^{th}$ day are presented in Figure.6 and Figure 7.The positive strain value represents the tensile strain and the negative strain value indicates the compressive strain. Fig.8 shows the comparison of concrete strain at the top surface and steel strain for all the beams at 28 and 56 days. These results revealed that GGBS concrete is able to achieve its full strain capacity under flexural loading.

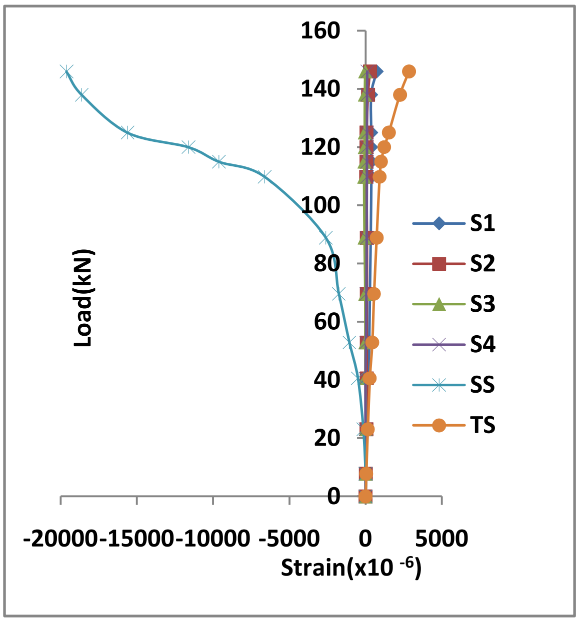



Fig.6. (a) CB 0% 1-28

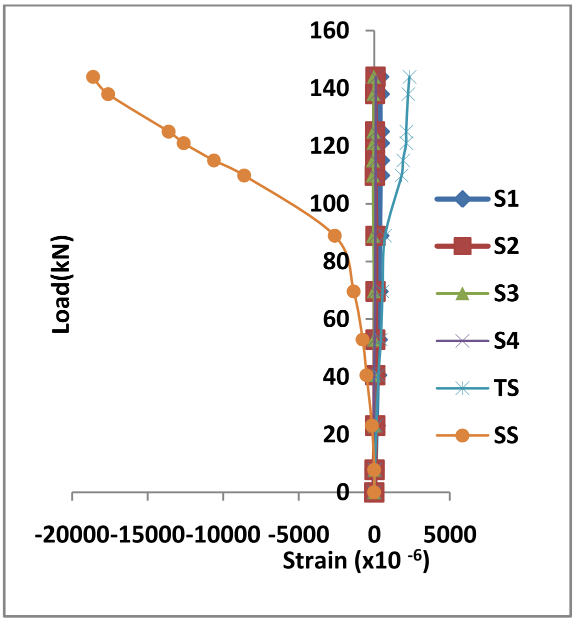



Fig.6 (b) CB 0% 2-28

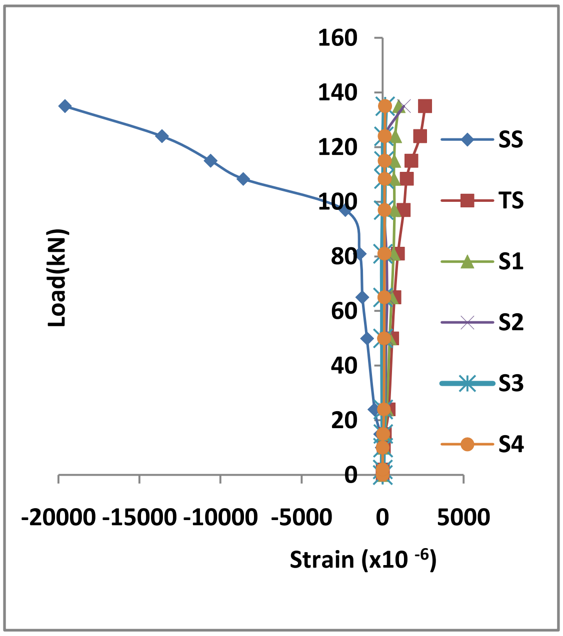



Fig.6 (c) GB 40% 1-28

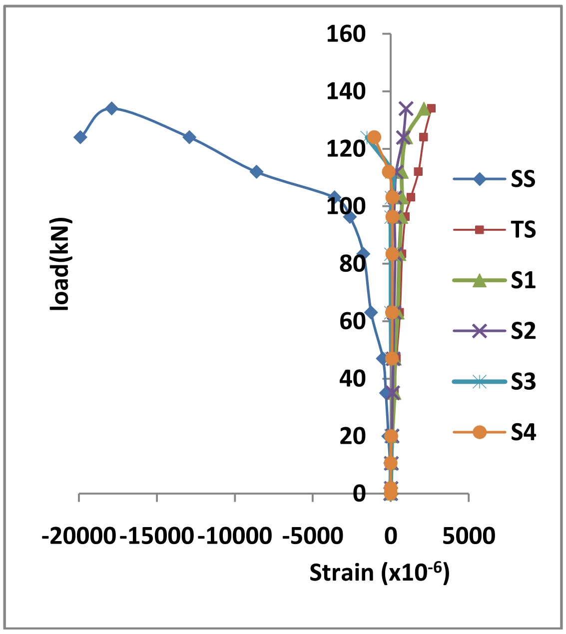
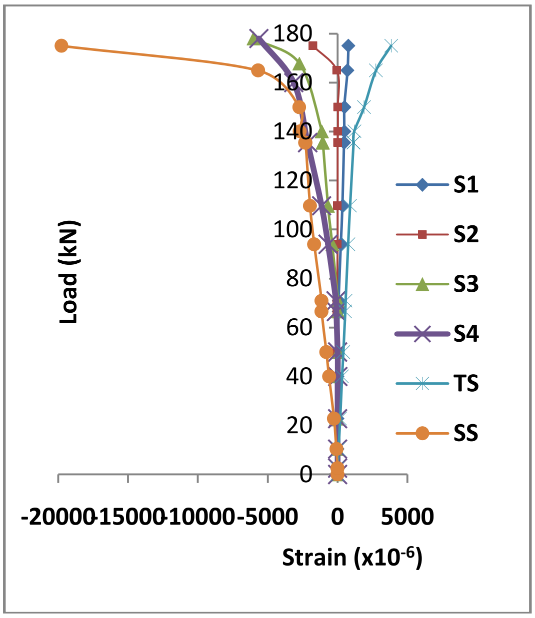



Fig.6 (d) GB4 0% 2-28

Fig.6: Load- Strain curves for beams tested at 28 days



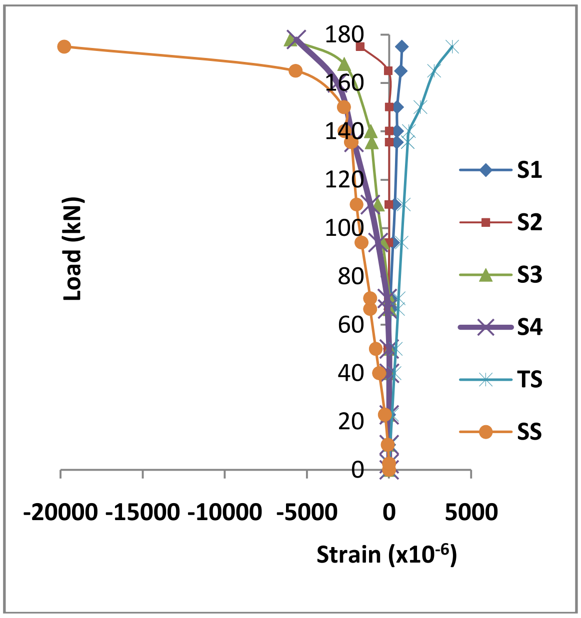
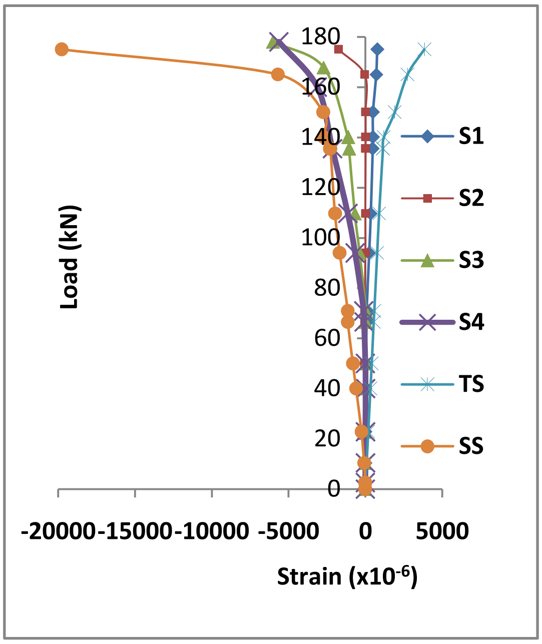




Fig.7 (a) CB0% 1-56 Fig.7 (b) CB0% 2-56



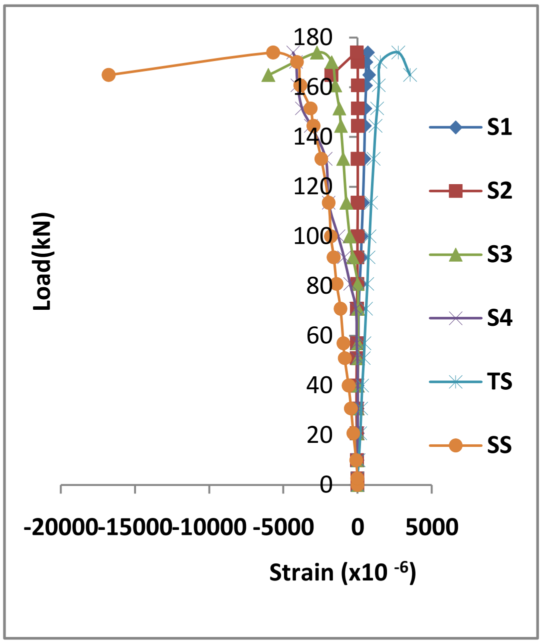




Fig.7 (c) GB 40% 1-56 Fig.7 (d) GB 40% 2-56

Fig. 7: Load- Strain curves for beams tested at 56 days

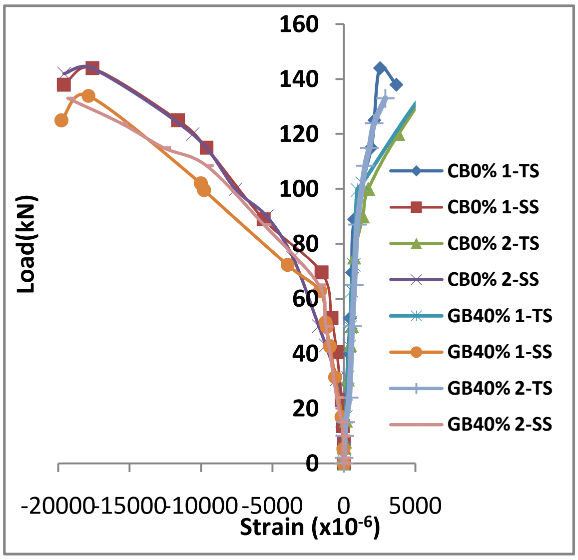



Fig.8 (a) At 28 days

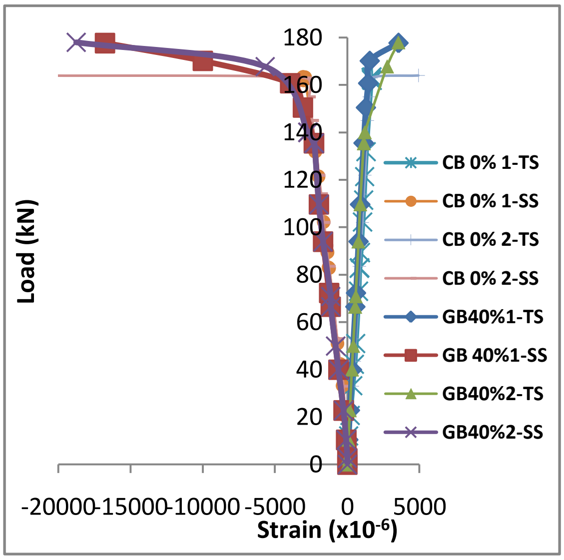



Fig.8 (b) At 56 days

Fig. 8: Comparison of Steel and Concrete Strain

### *3.4 Moment Curvature*

Moment-Curvature diagrams were generated for all the beams based on the concrete strain and steel strain. Curvature is computed from the average longitudinal compressive and tensile strains at the middle of the flange and centroid of the bottom reinforcement assuming a linear strain profile cross the cross section using the formula

$$\text{Curvature,} \quad \Phi = \frac{\varepsilon_c + \varepsilon_s}{d}$$

Where, $\varepsilon_c$ = Average longitudinal compressive strain in at the concrete fibre at the center of the flange

$\varepsilon_s$ = Average longitudinal tensile strain at the centroid of the tension steel

d = Distance between the compression and tension strain locations considered

Figure 9 shows the moment-curvature of the beams at 28th day and 56th day respectively. From the results the curvature of the beam with GGBS is found to be comparable with OPC concrete beams.

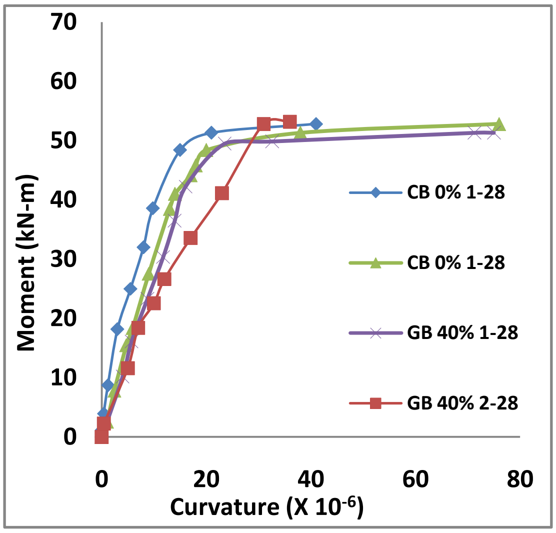



Fig.9 (a) At 28 days

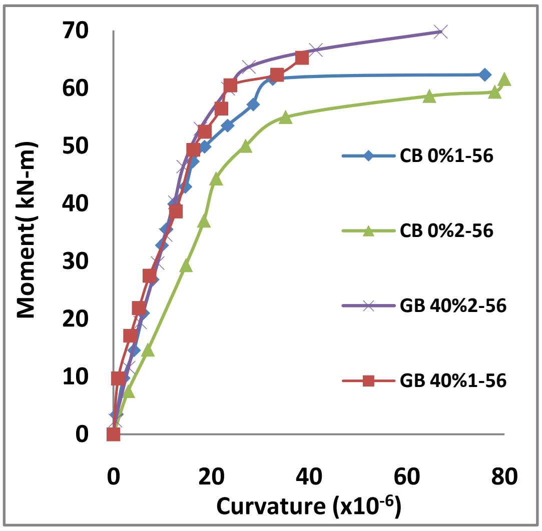



Fig.9 (b) At 56 days

Fig. 9: Moment Curvature for beams at 28 and 56 days

## IV. CONCLUSION

On the basis of experiments conducted on eight beam specimens the following observations and conclusions are drawn:

1. The ultimate moment capacity of GGBS was less than the controlled beam when tested at 28 days, but it increases by 21% at 56 days.
2. The deflections under the service loads for the concrete beams with 40% GGBS were same as that of the controlled beams at 28 days testing and it was quite less than controlled beams when tested at 56 days.
3. The measured crack width at service loads ranged between 0.17 to 0.2 mm and this is within the allowable limit prescribed by IS 456-2000.
4. The structural behavior of Reinforced concrete beams with GGBS resembled the typical behavior of Reinforced cement concrete beams and there is increase in load carrying capacity of GGBS beams with age. Hence results of this investigation suggest that concrete with 40% GGBS replacement for cement could be used for RC beams.

## REFERENCES


[1] K.Ganesh Babu,V. Sree Rama Kumar,"Efficiency of GGBS in concrete", Cement Concrete Research, Volume 30(7), pp.1031–1036,2000.

[2] VenuMalagavelli,P.N.RAO,"High performance concrete with GGBS and Robo sand", International Journal of Engineering Science and Technology, Vol. 2(10),pp.5107-5113,2010.

[3] K. Suvarna Latha, M V Seshagiri Rao, Srinivasa Reddy V," Estimation of GGBS and HVFA Strength Efficiencies in Concrete with Age", International Journal of Engineering and Advanced Technology (IJEAT) ,Vol 2(2): ISSN: 2249 – 8958,2012.

[4] Huiewn Wan and Zhonge Shui,"Analysis of geometric characteristics of GGBS particles and their influences on cement properties", Cement and Concrete Research.Vol.34(1),pp.133-137,2004.

[5] Ing Lim, Jenn-Chuan Chern, Tony Liu, and Yin-Wen Chan," Effect of ground granulated blast furnace slag on mechanical behavior of PVA-ECC", Journal of Marine Science and Technology,vol.20,pp. 319-324,2012.

[6] T. Suresh Babu, M.V. Seshagiri Rao and D. Rama Seshu," Mechanical Properties and stress- strain behaviour of self compacting concrete with and without glass fibres", Asian Journal of Civil Engineering (building and housing),vol. 9( 5),pp. 457-472,2008