ABSTRACT

The utilization of industrial by-products in construction sector could become an important route for large-scale safe disposal of the industrial wastes and reduction of construction cost. Ground Granulated Blast furnace Slag (GGBS) is a byproduct of the steel industry which can be partially replaced with cement to reduce significantly many of the environmental burdens associated with concrete. In this paper, the results of laboratory investigation conducted on the structural behavior of reinforced concrete beam with various replacement levels of GGBS are presented. Experimental investigation included testing of six reinforced concrete beams with and without GGBS. Portland cement was replaced with 30% and 40% GGBS. Glenium B233 was used as superplastisizer for the casting of beams to improve the workability. Two specimens were cast in each series. All the specimens were tested under two-point static loading. Data presented include the load-deflection characteristics, cracking behavior and stress strain characteristics of the reinforced concrete beams with and without GGBS when tested at 28th days and 56th days. The investigation revealed that the flexural behaviors of reinforced GGBS concrete beams are comparable to that of reinforced concrete beams.

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

1. INTRODUCTION

There is a wide spread attention directed towards the utilisation of wastes and industrial by-products in order to minimize Portland cement (PC) consumption, the manufacture of which being
Ground-granulated blast-furnace slag (GGBS) is an environmentally friendly by-product obtained by quenching molten iron slag from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. The GGBS when used as a cement replacement in hardened concrete results in significant enhancement of the basic characteristics of concrete, both of in its fresh and hardened states. The lower cement requirement also leads to a reduction for CO₂ generated by the production of cement [1–2]. Previous researches show that the addition of slag gradually improves the strength with age. Replacement of ordinary Portland cement with ground granulated blast furnace slag up to an optimum percentage of 50 has found to increase the fresh and hardened properties of concrete [3-5]. The addition of GGBS can be a suitable method of improving the durability of concrete and it was suggested that GGBS is generally beneficial in extending the life of concrete [6,7]. The stress-strain relationship of beams with GGBS is also found to be comparable with those of ordinary concrete [8-9]. In this investigation, the stress-strain behavior of reinforced concrete beams with and without 30% and 40% addition of GGBS was carried out. Superplasticiser was used to improve workability and to reduce shrinkage effects. Twelve beams were cast and subjected to two point loading. Data presented include deflection characteristics, cracking behavior, stress-strain characteristics at 28 days and 56 days.

2. EXPERIMENTAL INVESTIGATION

2.1 Mix details

The materials used in the Mix Design were Ordinary Portland cement (OPC), river sand, aggregate, GGBS and potable water. To improve workability a polycarboxylic ether based superplasticiser, Glenium B233 was used in the mix with 30% and 40% GGBS. Water binder ratio of 0.36 and 0.4% of superplasticiser were used for concrete Beams. Fe 500 grade steel was used for longitudinal reinforcement and for stirrups.

2.2 Specimen details

The specimens were 150mm wide and 250mm deep in cross-section and 2500mm in length. The clear cover of the beam was 20mm. 3#12 mm diameter bars were provided @ tension side and 2#10mm diameter bars were provided @ compression side. Two legged vertical stirrups of 8 mm diameter at a spacing of 160 mm centre to centre were provided as shear reinforcement. Twelve numbers of reinforced concrete beams with and without GGBS were cast and tested in the loading frame of 40 T. Out of the 12 specimens tested, 4 specimens were cast without GGBS, and 4 specimens were cast with 30% GGBS an four specimens with 40% GGBS. Two specimens were cast in each series. Six specimens were tested at 28th day and remaining six specimens were tested at 56th day from the date of casting. The test setup is shown in Figure 1. Strain gauges of 0.2mm were fixed directly fixed in to the reinforcement surface with high skilled labors. LVDT’s were used for measuring deflections. Strain gauges and LVDT’s were connected to a data logger from which the readings were captured by a computer at every load intervals. 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.
3. 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. All the measurements including deflections, strain values and crack widths were recorded at regular intervals of load until the beam failed. Figure 3 shows the failure pattern of the test specimens. 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. The failure patterns of the beams are shown in figure 2.

3.2. Deflection at Various Load Stages

The experimental load-deflection curves of the RC beams with 30%, 40% GGBS and without GGBS when tested at 28th day and 56th day are shown in Figure 3 and Figure 4 respectively. The average ultimate loads for reinforced OPC concrete beams, 30% GGBS and 40% GGBS concrete beams are 144 kN, 138 kN & 134 kN respectively at 28th day and it is 164 kN, 169 kN & 168 kN respectively at 56th day. Though the ultimate loads for the concrete beam with GGBS is less than the OPC beams at 28th day and 56th day respectively, its ultimate load increases at 56th day.
Figure 3: Load-Deflection curves for the beams tested at 28\textsuperscript{th} days
Figure 4: Load-Deflection curves for the beams tested at 56th days
3.3 Concrete and steel strain

The concrete and steel strains measured at every load increments are presented in Figure 5 and 6 which shows the strain distribution for the concrete and steel at 28\textsuperscript{th} day and 56\textsuperscript{th} respectively. The positive strain value represents the tensile strain and the negative strain value indicates the compressive strain. These results revealed that GGBS concrete is able to achieve its full strain capacity under flexural loading.

\textbf{Figure 5:} Load-Strain curves for beams tested at 28\textsuperscript{th} days
**Figure 6:** Load-Strain curves for beams tested at 56$^{th}$ days
4. CONCLUSION

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

- The ultimate moment capacity of GGBS was less than the controlled beam when tested at 28 days, but at 56 days it was equivalent to Controlled beam.
- The maximum deflections for OPCC specimens were almost same as GGBS specimens at 56 days. The deflections under the service loads for the concrete beams with 30% was quite larger than the beams with 40% GGBS at 28 days. From the experimental results it is observed that increase in percentage of GGBS has reduced the deflection.
- 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 GGBS can be replaced for cement up to 40%

REFERENCES