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Flexural Behaviour Of Reinforced Concrete Beams With Ggbs

C. SIVAPRABHAKAR
PG Student, Department of Civil Engineering,
PRIST University, Thanjavur, Tamil Nadu, India.

***Abstract*— Ground Granulated Blast furnace Slag is a by-product of iron manufacturing industry. Iron ore, coke and limestone are fed into the furnace, and the resulting molten slag floats above the molten iron at a temperature of about 1500oC to 1600oC. The molten slag has a composition of 30% to 40% Silicon Dioxide (SiO2) and approximately 40% Calcium Oxide (CaO), which is close to the chemical composition of Portland cement. This paper presents the flexural behaviour of reinforced concrete beams with GGBS.**

I. Introduction

Concrete is typically the most massive individual material element in the built environment. If the embodied energy of concrete can be reduced without decreasing the performance or increasing the cost, significant environmental and economic benefits may be realized. Concrete is primarily comprised of portland cement, aggregates and water. Although portland cement typically comprises only 12% of the concrete mass, it accounts for approximately 93% of the total embodied energy of concrete and 6% to 7% of the world wide Carbon dioxide (CO_2) emissions. Besides this, dust emission during cement manufacturing is one of the main issues facing the industry. The industry handles millions of tons of dry material. Even if 0.1% of this is lost to the atmosphere, it can cause havoc environmentally. This has made the researchers worldwide to look for addition of cementitious materials in concrete to reduce the usage of cement in concrete. Efforts are being carried out to conserve energy by means of promoting the use of industrial wastes or byproducts, which contain amorphous silica in its chemical composition, as a mineral admixture for partial replacement of cement. The utilization of pozzolanic materials in concrete as partial replacement of cement is gaining immense importance today, mainly on account of the improvements in the long-term durability of concrete. The pozzolanic materials are classified into two categories. They are natural pozzolans, which are of volcanic origin and man-made pozzolans, which include industrial by-products such as Fly Ash (FA), Ground Granulated Blast furnace Slag (GGBS), Rice Husk Ash (RHA), Silica Fume (SF), etc. The use of pozzolanic material based blended cement concrete is growing rapidly in the construction industry, which will result in saving of energy, environmental protection and conservation of resources.

Matsuda et al (2005) investigated the applications of GGBS to reduce seismic earth pressure. GGBS shows a similar particle formation similar to natural sand and also low weight, high shear strength, well permeability and especially a latent hydraulic property by which GGBS hardens like a rock. Model wall tests were carried out on GGBS, in which the resultant earth pressure, wall friction and the earth pressure distribution at the wall surface were measured, and the test results were compared with those of standard sand. It was clarified that the resultant earth pressure obtained by using GGBS was smaller than sand, especially in the active-earth pressure side.

Gauld and Jasen (2006) pointed out that the latent hydraulic binder that can be used in conjunction with cement is GGBS, to produce portland slag or blast furnace cements. The material is an ideal choice in both general and specialized concretes due to the merits of GGBS within concrete. They had concluded that if certain level of cement is replaced with GGBS in concrete, it gives greater resistance to sulfate attack, reduced chloride ion diffusion, lower early-age temperature rise and benefits from longer-term strength development.

Chen et al (2007) conducted experiments on the mortar made up of ground granulated blast furnace, gypsum, clinker and steel slag sand. The experimental results showed that the application of steel slag sand reduced the dosage of cement clinker and increased the content of industrial waste product using steel slag sand.

Sata et al (2007) experimentally investigated the effects of pozzolano made from various by-product materials such as Ground pulverized coal combustion Fly Ash (FA), ground fluidized bed combustion GGBS (FB), ground rice husk–bark ash (RHBA), and ground palm oil fuel ash (POFA) on mechanical properties of high-strength concrete. The results suggested that concrete containing FA, FB, RHBA, and POFA can be used as pozzolanic materials in making high-strength concrete with 28 days compressive strengths higher than 80 MPa. After 7 days of curing, the concrete containing 10-40% FA or FB and 10-30% RHBA or POFA exhibited higher compressive strengths than that of the control concrete.

Elsayed (2011) investigated experimentally in his studies, the effects of mineral admixtures on water permeability and compressive strength of concrete containing Silica Fume (SF) and GGBS (FA). The results were compared to the control concrete, ordinary portland cement concrete without admixtures. The optimum cement replacement by FA and SF in this experiment was 10%. It was concluded that the strength and permeability of concrete containing silica fume, GGBS and high slag cement could be beneficial in the utilization of these waste materials in concrete work, especially in terms of durability.

The possibility of utilizing steel slag as aggregates in concrete was experimentally investigated by Netinger et al (2011). Aggregate properties were determined on coarse slag fractions according to the relevant European Standards. Based on the obtained results, it was proved that coarse slag fractions can be suitable for concrete application. Therefore, concrete mixtures were prepared with coarse slag fractions whose hardened state properties like compressive and flexural strength, static modulus of elasticity, volume changes and corrosion susceptibility were then compared with the properties of reference concrete made of commonly used natural aggregate materials. The authors concluded that the observed slags can be a good substitute for natural aggregate materials.

Yogendra et al (2013) presented the experimental study on flexural strength of concrete prepared with OPC, partially replaced by GGBS in different proportions varying from 0% to 40%. It was observed from the investigation that the strength of concrete is inversely proportional to the percentage of replacement of cement with GGBS. The authors had concluded that up to 20% replacement of cement is possible without compromising the strength with 90 days curing.

Madheswaran et al (2014) investigated the flexural behaviour of reinforced Geo Polymer Concrete (GPC) incorporating synthetic light weight aggregate. Four sets of reinforced GPC beams (two specimens each) having different mix composition incorporating GGBS aggregate and having reinforcement equal to 1.33 and 2.17% of balanced section were tested for flexural behaviour under two point loading up to failure. The deflection, cracking load, failure load, and crack pattern at failure load were recorded. The ultimate load capacities ranged from 53.3kN to 64.85kN for 100% reinforcement and 24kN to 32.6kN for 50% reinforcement and about 10% difference was observed due to mix variations. The ratio of experimental to theoretical moment capacity ranged from 0.92 to 1.0. The ultimate moment carrying capacity of beams tested was calculated from the first principles using strain compatibility methods and provisions of IS 456:2000.

III. EXPERIMENTAL RESULTS

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.

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 Figure1 & 2 respectively. The average ultimate loads for controlled beams and 40% GGBS concrete beams are 144 kN and 135 kN respectively at 28th day and it is 164 kN and 178kN at 56th day. Though the ultimate loads for the Beams with 40% GGBS is less than that of the controlled beams at 28th day, its ultimate load increases at 56th day.

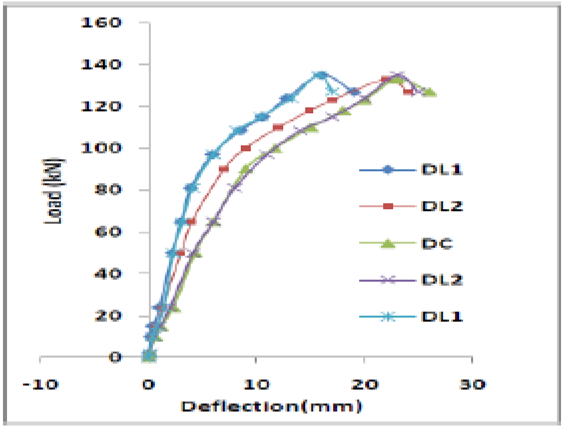

Fig 1: Load- Deflection curves for the beams tested at 28 days

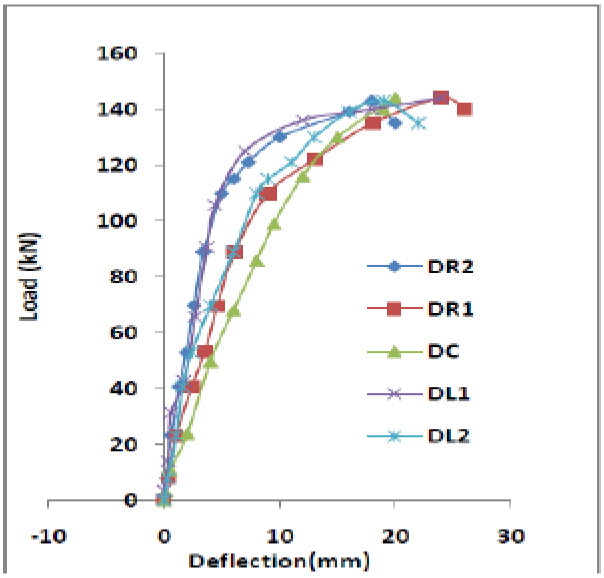

Fig. 2. Load- Deflection curves for the beams tested at 56 days

CONCLUSIONS

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.

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