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FLEXURE AND CRACKING BEHAVIOR OF RC BEAMS BY PARTIAL REPLACEMENT OF CEMENT WITH GGBS

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Abstract- ***Ordinary Portland cement (OPC) is one the main materials used in casting reinforced concrete (RC) structures. However, it causes the emission of a significant amount of CO_2 to the atmosphere and therefore contributes widely to the formation of the greenhouse effect. The increasing use of such OPC materials in construction projects had led to the initiation of global environmental warming. The utilization of industrial by-product 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 by-product of the steel industry which can be partially replaced with cement to reduce significantly many of the environmental burdens associated with concrete. Polypropylene fibers tend to hold the concrete mix together. This slows the settlement of coarse aggregate and thus reduces the rate of bleeding. This paper presents, the flexure and cracking behavior of RC beams by partial replacement of cement with GGBS of 0%, 50% and 70%. Addition of polypropylene fibers decreases the unit weight of concrete and increases its strength. 0.5% of polypropylene is added to cement. Experimental investigation included testing of six reinforced concrete beams with and without GGBS. Portland cement is replaced with 50% and 70% GGBS. 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. In addition, the concrete compressive and tensile strength of the different mixes were evaluated at 7, 28 and 56 days. All the beam specimen were tested on the two point loading. Data presented include the load-deflection characteristics, cracking behavior of the reinforced concrete beams with and without GGBS when tested at 28 and 56 days. The investigation revealed that the compressive and split tensile strength decreases by increasing of GGBS percentage, but increases with age. The ultimate loading capacity of the beam specimens with 50% and 70% GGBS replacement are higher than that of the without GGBS specimen by 2% and 3% respectively.***

Keywords: Ground Granulated Blast furnace slag, cement, polypropylene fibers, compressive strength, flexural strength, reinforced concrete beams.

I .INTRODUCTION

Ordinary Portland cement (OPC) is one of the main materials used in casting reinforced concrete (RC) structures. However, it causes the emission of a significant amount of CO_2 to the atmosphere and therefore contributes widely to the formation of the greenhouse effect. The increasing use of such OPC materials in construction projects had led to the initiation of global environmental warming. This is due to the fact that for each ton of produced OPC approximately a ton of CO_2 is released to the atmosphere. Therefore, one of the main focuses of corporations was to reduce the use of OPC or to find a better alternative material in order to reduce its impact on the environment.

One of the known alternative materials to OPC in the concrete mix is Ground Granulated Blast Furnace Slag (GGBS). GGBS is a byproduct extracted from blast furnaces used to produce iron. The chemical properties of GGBS are composed of a non-metallic product which is known as blast furnace slag that consists of silicates and alumni-silicate of calcium with different bases and a metallic product which consist of iron and manganese. In addition, it has two different phases, glassy and crystalline. Due to its physical and chemical properties, GGBS can be highly effective in enhancing the durability and corrosion resistance of concrete structures. Since GGBS is a very finely glassy powder, it increases the bond between particles, and it reduces the permeability of concrete, and thus can protect the internal steel reinforcement from corrosion.

Polypropylene fibers tend to hold the concrete mix together. This slows the settlement of coarse aggregate and thus reduces the rate of bleeding. The application of the fibers in construction increased largely because addition of fibers in concrete improves the split tensile strength, flexural strength, toughness, impact strength and the failure mode of concrete. Addition of polypropylene fibers decreases the unit weight of concrete and increase its strength.

II. METHODOLOGY

The materials were properly mixed in dry condition and polypropylene fiber were taken to the weight of cement as 0.5%. Different percentages of GGBS were added to the concrete mix which is of 0%, 50% and 70%. The water cement ratio of 0.5 was used to prepare the concrete mix. Cubes and cylinders were casted of three each mix and cured at 7, 28 and 56 days. After the curing period the specimens were subjected to testing under compression testing machine. Totally 6 number of beam specimens were casted and cured for 28 and 56 days. After the curing period the specimens were subjected to testing using loading frame setup.

III EXPERIMENTAL INVESTIGATION

3.1 Mix details

The materials used in the Mix design were Ordinary Portland cement (OPC-53 grade), sand, aggregate, GGBS and potable water. The fibers usually have effect on compressive strength, which slightly increases the test results by adding of 0.5%. Fe 500 grade steel was used

3.2 Mix design for M20 grade concrete

Materials	**Cement**	**Fine Aggregate**	**Coarse aggregate**	**Water(lit)**
Quantity (kg/m^3)	387	623	1192	193
Proportions	1	1.61	3.1	0.5

3.3Compression Test and split tensile test

The compression test was conducted on cube specimens properly cured for 7, 28 and 56 days. The top and bottom bearing plates of the compression testing machine were wiped and cleaned before the placement of the cube specimen. Cube moulds of size 150 x 150 x 150 mm were casted and allowed for curing tank for 7, 28 and 56 days. Compressive strength (MPa) = failure load / cross sectional area.

For tensile strength test, cylinder specimens of dimension 150mm diameter and 300mm length were cast. These specimens were tested under compression testing machine.

Tensile strength (MPa) = 2P / πDL

Figure 1: Compression testing machine

Figure 2: split tensile test

Figure 3: compressive test

Table:1 Compression test and Split tensile test 0.5% polypropylene fiber added mix

Type of concrete	Age of concrete	Average compression strength(N/mm^2)	Average split tensile strength(N/mm^2)
0%GGBS, 0.5%polypropylene	7 days	31.68	3.39
	28 days	46.96	3.11
	56 days	56.3	2.9
50% GGBS, 0.5% polypropylene	7 days	25.29	2.97
	28 days	41.18	3.11
	56 days	31.85	2.76
70%GGBS, 0.5% polypropylene	7 days	20.203	2.76
	28 days	39.4	2.76
	56 days	31.85	2.48

3.4 Specimen details

The specimens were 100mm wide and 150mm deep in cross-section and 1300mm length. The clear cover of beam was 25mm. 2#12mm bars diameter bars were provided @ tension side and 2#6mm diameter bars were provided @ compression side. Two legged vertical stirrups of 6mm diameter at a spacing of 90mm centre to centre. Six numbers of reinforced concrete beams with and without GGBS were cast and tested in the 100 T loading frame setup. Out of six specimens tested, 2 specimens were cast without GGBS but contains 0.5% polypropylene, 2 specimens were cast with 50% GGBS and 0.5% polypropylene and 2 specimens were cast with 70% GGBS and 0.5% polypropylene. Three specimens were tested at 28th day and remaining three specimens were tested at 56th day.

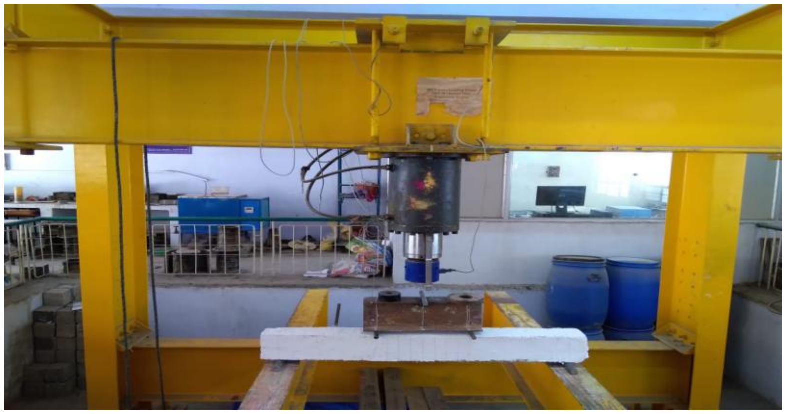

Figure:4 Experimental set-up for test specimens

IV RESULTS AND DISCUSSIONS

4.1 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 beam with and without GGBS. It was noticed that the first crack always appears close to the mid span of the beam.

Figure: 5 Failure pattern of the beams

, 50% GGBS 0.5% polypropylene and 70% GGBS 0.5% polypropylene concrete beams are 25 KN, 44 KN and 46 KN respectively at 28th day and it is 46.3KN, 53KN and 54.7KN respectively at 56th day. Though the ultimate loads for the concrete beams with GGBS (0.5% polypropylene) is more than the OPC (0.5% polypropylene) beams at 28th day and 56th day respectively, its ultimate load increases at 56th day.

Figure: 6 First crack of RC beams

4.2 *First Crack Load*

The first cracking load was the load where the first signs of cracking occur on the side of the test specimen. Loads at first cracking from the experimental results are illustrated in figure 7. It can be seen from the figure that the strength at the first crack is increased with the addition of 0.5% polypropylene and increases of GGBS percentage.

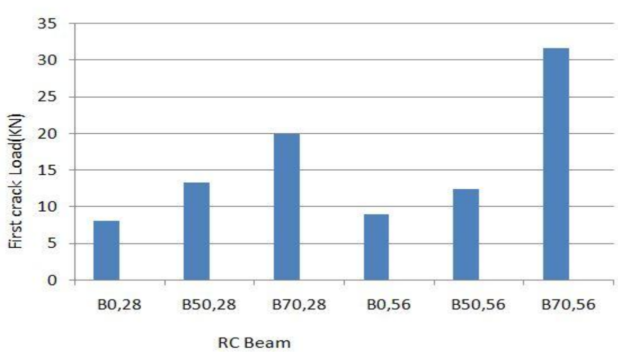

Figure:7 First Crack load of beams

4.3 *Cracks patterns*

The crack patterns were very similar in all beam specimens, the first crack occurred at different load levels within the constant moment zone. Flexural cracking consisting of vertical cracks perpendicular to the direction of the principal tensile stress occurred early at mid-span. As the load increased, the vertical flexural cracks spread horizontally from the mid-span to the support. At a higher load, additional cracks started to form throughout the length of the specimen, propagating upward.

Figure: 8 Cracks patterns of RC beams

4.4 *Load vs. Deflection Characteristics*

The behavior of load and deflection is the principal constituent of the flexural behavior of the beam, as the load increases the deflection also increases up to a particular limit. The load will partially increase to compare 0.5% polypropylene beam with 0.5% polypropylene and different percentages of GGBS.

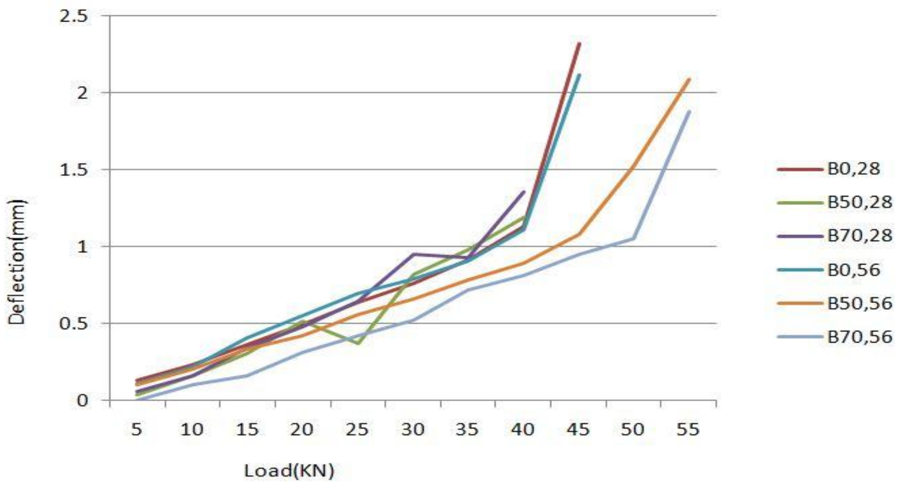

Figure:9 Load vs Deflection Curve for all speciemns

4.5 *Flexure strength*

Flexural strength, also known as modulus of rupture, or bend strength, or transverse rupture strength is a material property, defined as the stress in a material just before it yields in a flexure test. The flexural strength represents the highest stress experienced within the material at its moment of yield.

Table:2 Flexural strength in N/mm^2

Beam mix	polypropylene	Flexural strength(N/mm^2)
M1,28	0.5	12.72
M2,28	0.5	22.34
M3,28	0.5	23.81
M1,56	0.5	23.67
M2,56	0.5	27.45
M3,56	0.5	28.12

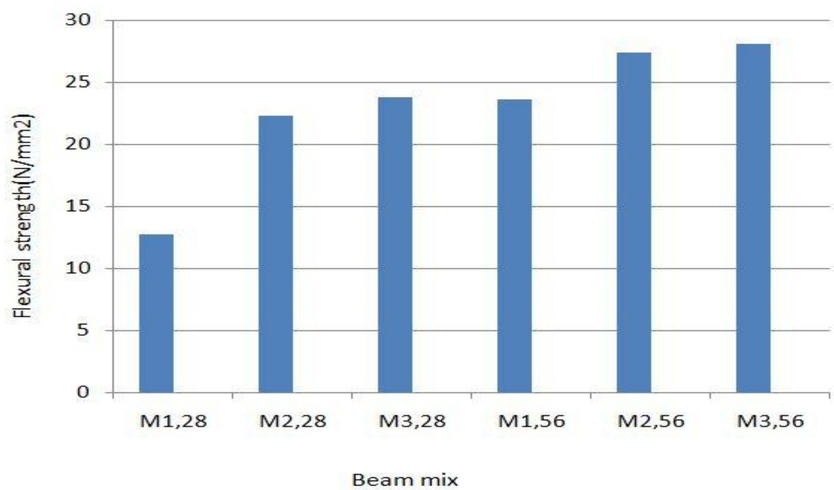

Figure:10 Graph column between beam mix and flexural strength

V CONCLUSION

The following observations and conclusions were based on the obtained experimental results.

- The achieved compressive and tensile strength of different mixtures with 50% and 70% GGBS are deceasing by comparing to 0%GGBS(0.5%polypropylene), but increasing by its age.
- The tested reinforced concrete beam specimens failed as expected in a flexural mode by yielding of the longitudinal bottom tension reinforcement and top concrete crushing the two loading supports.
- The load-deflection curves of the specimens with different percentages of GGBS(0.5% polypropylen) replacement is quite similar to that without GGBS(0.5% polypropylne).
- The ultimate load capacity of the beam specimen with 50% and 70% GGBS replacement are higher than that of the without GGBS by 2% and 4% respectively.
- Utilizing high percentage of GGBS replacement to cement up to 70% in concrete mixes would be practical in the construction market.
- In the modernworld concrete is the fundamental material in the construction field. To improving the mechanical properties of concrete by adding this fibers to composite material to increase strength and durable on future.

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