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GGBS as Partial Replacement of OPC in Cement Concrete – An Experimental Study

Engineering

KEYWORDS : Compressive Strength, Concrete, Flexural Strength, Ground Granulated Blast Furnace Slag, Ordinary Portland Cement

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ABSTRACT

The production of cement results in emission of many green house gases in atmosphere, which are responsible for global warming. Hence, the researches are currently focussed on use of waste material having cementing properties, which can be added in cement concrete as partial replacement of cement, without compromising on its strength and durability, which will result in decrease of cement production thus reduction in emission in green house gases, in addition to sustainable management of the waste. The ground granulated blast furnace slag is a waste product from the iron manufacturing industry, which may be used as partial replacement of cement in concrete due to its inherent cementing properties. This paper presents an experimental study of compressive and flexural strength of concrete prepared with Ordinary Portland Cement, partially replaced by ground granulated blast furnace slag in different proportions varying from 0% to 40%. It is observed from the investigation that the strength of concrete is inversely proportional to the % of replacement of cement with ground granulated blast furnace slag. It is concluded that the 20% replacement of cement is possible without compromising the strength with 90 days curing.

I. INTRODUCTION

The production of cement is an energy intensive process, resulting in emission of green house gases which adversely impact on the environment. At the same the cost of production of cement is increasing at alarming rate and natural resources giving the raw material for its manufacturing are depleting. The use of waste material having cementitious properties as a replacement of cement in cement concrete has become the thrust area for construction material experts and researchers. The main focus now a days is on search of waste material or bye product from manufacturing processes, which can be used as partial replacement of cement in concrete, without compromising on its desired strength. The ground granulated blast furnace slag (GGBS) is a waste product from the iron manufacturing industry, which may be used as partial replacement of cement in concrete due to its inherent cementing properties. In the country like India, where the development of the infrastructures projects such as large irrigation, road and building projects are either being constructed or in completion of their planning and design stage, such uses of waste material in cement concrete will not only reduce the emission of green house gases but also will be the sustainable way of management of waste. The Fly ash (FA), GGBS, Rice Husk Ash (RHA), Silica Fume (SF) are some of the pozzolanic materials which can be used in concrete as partial replacement of cement. A number of studies are going on in India as well as abroad to study the impact of use of these pozzolanic materials as cement replacements and the results are encouraging. These materials include fly ash, silica fume and ground-granulated blast furnace slag used separately or in combination. The strength, durability and other characteristic of concrete depends on the properties of its ingredients, proportion of mix, method of compaction and other controls during placing and curing. For concretes, a combination of mineral and chemical admixtures is always essential to ensure achievement of the required strength.

II. LITERATURE REVIEW

Many investigators have researched on replacement of GGBS with cement in concrete and found the encouraging results. It is observed that the curing period required for GGBS concrete is more as compared to normal concrete [Parniani *et al.* (2011) & Dubey *et. al.* (2012)]. It is concluded by Khan & Usman (2003) that workability of GGBS concrete is more and thus water cement ratio may be reduced resulting in increase in compressive strength. Shariq *et. al.* (2008) found in his experiments that the replacement of OPC in concrete with GGBS gives the optimum strength at 40% but after curing of 56 days. Naidu *et al.*(2012) researched on geopolymer concrete with addition of GGBS and found the increase in strength of concrete. The GGBS concrete gives better performance than normal concrete when exposed to aggressive environment [Muhamad and Emmanual (2000), Basu and Ramakumar (2007)]. Barnett *et al.* (2006) concluded from their research that the early strength development of mixtures containing GGBS is highly dependent on temperature under standard curing conditions and the GGBS mortar gain strength more slowly than mortars with OPC.

III. MATERIAL AND METHOD

The GGBS is a by-product in the manufacture of iron and the amounts of iron and slag obtained are of the same order. 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 1500°C to 1600°C. After the molten iron is tapped off, the remaining molten slag, which consists of mainly siliceous and aluminous residue is then water-quenched rapidly, resulting in the formation of a glassy granulate. This glassy granulate is dried and ground to the required size, which is known as GGBS. The GGBS required in this study obtained from Ispats steel plant Surat. The GGBS which is used passes, 90% through 90 micron sieve. The aim of this work is to ascertain the performance of concrete mix containing GGBS as replacement of OPC and to compare it with the plain concrete mix of 20 grades.

The chemical composition of GGBS is obtained from X-ray analysis at laboratoary and is shown in Table – 1.

Table – 1 : Chemical Composition of GGBS

Constituents	%
SiO_2	34.4
Al_2O_3	21.5
Fe_2O_3	0.2
CaO	33.2
MgO	9.5
K_2O	0.39
Na_2O	0.34
SO_3	0.66

The cement is a material that has cohesive and adhesive properties in the presence of water, consist primarily of silicates and aluminates of lime. The OPC (53 Grade) is used for this study. The fine aggregate are material passing through an IS sieve that is less than 4.75 mm gauge beyond which they are known as coarse aggregate. The main function of the fine aggregate is to provide workability and uniformity in the mixture. The fine aggregate uses in this study is locally available river sand which conforms to zone III as per BIS code. The coarse aggregate form the main matrix of the concrete, where as fine aggregate form the filler matrix between the coarse aggregate. The maximum size of aggregate used in this study is 20 mm. The coarse aggregate is confirmed by IS 383:1977 and is 20 mm maximum size. The cement, fine and coarse aggregates required for experimentation are tested in the laboratory and the results are shown in Table – 2.

Table – 2 : Properties of OPC, Fine and Coarse Aggregate

Properties	Value
(a) Cement	
Specific gravity	3.15
Initial setting time	75 min
Final setting time	360 min
(b) Fine Aggregate	
Specific gravity	2.65
Water absorption	1%
Fineness modulus	3.3
(c) Coarse Aggregate	
Specific gravity	2.68
Water absorption	0.5%
Fineness modulus	7.02

IV. EXPERIMENTAL PROGRAMS

The cement concrete mix is prepared as per the procedure given in the BIS 10262:2009. For optimal dosage selection of GGBS in concrete mix, modified cubes (percentage ranging from 10% to 40%) are prepared and compared with plain cement concrete cubes and beams with mix proportion of 1:1.59:3.05 are prepared. The replacements of OPC with GGBS are made on an equal weight basis. The w/c ratio is taken 0.5% for all the mixes. The result of mix design of the concrete is shown in Table – 3.

Table – 3 : Mix Specification for 1 m^3 Concrete

Particulars	Plain concrete mix	10%	20%	30%	40%
Cement in kg/m^3	383	344.7	306.4	268	230
Sand in kg/m^3	610	610	610	610	610
Coarse aggregate in kg/m^3	1170.5	1170.5	1170.5	1170.5	1170.5
GGBS in kg/m^3	0	38.3	76.6	115	153
Water in kg/m^3	191.6	191.6	191.6	191.6	191.6

In this investigation 45 cubes and 45 beam specimen are tested. The Cubes with the dimension of 150 x 150 x 150 mm and beams with dimension of 150 x 150 x 750 mm are prepared for each batch of mixes to measure compressive strength and flexural strength of concrete respectively at the age of 7 days, 28 days and 90 days of curing.

All the specimens are kept in water tank for curing and thereafter tested as per BIS norms and standard. All the cube specimens are tested for compressive strength in compression testing machine (CTM) and all beam specimens are tested for flexural strength in universal testing machine (UTM). The

V. RESULT

The compressive strength and flexural strength of cement concrete containing various % of GGBS at the age of 7, 28 and 90 days are given in Table 4 and 5 respectively.

Concrete Types	Compressive Strength		
	7 Days	28 Days	90 Days
100%OPC	12.62	21.37	24.30
10%GGBS 90%OPC	12.29	21.17	23.94
20%GGBS 80%OPC	10.98	20.72	23.50
30%GGBS 70%OPC	9.67	19.54	21.45
40%GGBS 60%OPC	8.48	18.32	19.24

Table – 4 : Compressive Strength (N/mm^2)

Table – 5 : Flexural Strength Test Results (N/mm^2)

Concrete Types	Flexural Strength		
	7 Days	28 Days	90 Days
100%OPC	2.25	3.39	3.85
10%GGBS 90%OPC	2.00	3.12	3.75
20%GGBS 80%OPC	1.85	2.90	3.62
30%GGBS 70%OPC	1.40	2.70	3.25
40%GGBS 60%OPC	1.35	2.64	2.89

VI. DISCUSSION AND CONCLUSIONS

The main aim of the study is to obtain the suitability of GGBS as replacement of OPC in concrete. The results of compression test and flexural test are shown in graphical form in Figure – 1 and 2. It may be observed from the plots that the properties of can be maintained with GGBS as partial replacement of cement up to 20%.

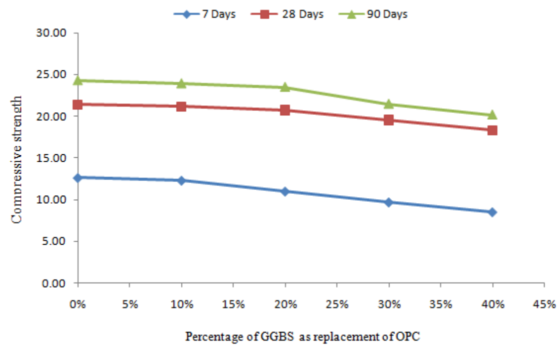

Figure – 1 : Compression Test Result

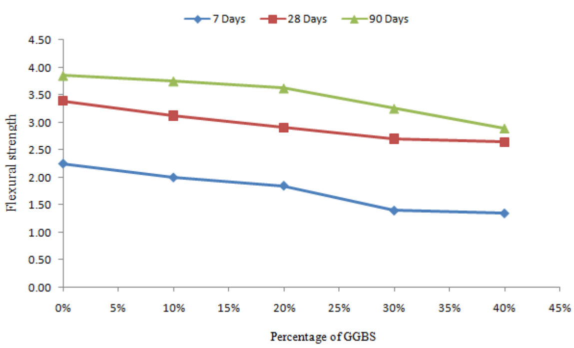

Figure – 2 : Flexural Test Result

As far as cost is concern the cost of GGBS in market including packaging and transport is three times less than that of OPC. Thus in one cum of concrete, 20% replacement of GGBS with OPC results in 14% reduction in cost of concrete. At the same time durability of concrete increases, due to inherent property of GGBS to protect concrete against chemical corrosion.

The following conclusions are drawn from the study –

- The increase in % of GGBS results in decrease in strength of concrete.
- The replacement of OPC by GGBS up to 20 % shows the marginal reduction of 4~6% in compressive and flexural strength for 90 days curing; however beyond 20% replacement by GGBS the reduction in strength is substantial i.e. more than 15%.
- The reduction in the cost of concrete at the current market rate is 14%, in the case of GGBS as replacement of OPC by 20%.
- The partial replacement of OPC in concrete by GGBS, not only provides the economy in the construction but it also facilitates environmental friendly disposal of the waste slag which is generated in huge quantities from the steel industries.

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