An Experimental Investigation of Ground Granulated Blast Furnace Slag (GGBS) on Concrete

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Abstract— The usage of cementitious materials is getting more and more intense with the advanced development in infrastructure area. In order to reduce usage of cement in concrete, Ground Granulated Blast Furnace Slag (GGBS) can be used as the replacement material [1]. GGBS is obtained by quenching molten iron slag from a blast furnace in water or steam to produce a glassy, a granular product that is then dried and ground into a fine powder. The effects of various percentages of GGBS (5, 10, 15, 20, 25, 30, 35 & 40) were investigated. The fresh and hardened properties of GGBS concrete is then compared with Normal Concrete (M35). GGBS Concrete with 5% Replacement results in higher strength.

Key words: Granulated Blast Furnace Slag (GGBS), Concrete

I. INTRODUCTION

Cement is a binder, a substance used in construction that sets, hardens and adheres to other materials, binding them together. Cement used in construction are usually inorganic, often lime or calcium silicate based and can be characterized as being either hydraulic or non-hydraulic, depending upon the ability of the cement to set in the presence of water. Cement is used with fine aggregate to produce mortar for masonry or with sand and gravel aggregates to produce concrete. The raw materials needed to produce cement are generally extracted from lime stone rock, chalk, shale or clay. These raw materials are taken from quarry by either extraction or blasting. These naturally occurring minerals are then crushed through a milling process. At this stage, additional minerals are added to ensure the correct chemical composition for making cement. These minerals can be obtained from the waste or by products of other industries, such as GGBS.

The most common mineral in which cement can be replaced is Ground Granulated Blast Furnace Slag (GGBS), can be 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 chemical composition of slag varies considerably depending on the composition of the raw materials in the iron production process [2]. The main components of blast furnace slag are shown in Table I. The GGBS can be added to concrete along with Portland cement, aggregates and water. The normal ratios of aggregates and water to cementitious materials in the mix remain unchanged. GGBS provides resistance against both sulphate attack and chloride attack. Concrete containing GGBS cement has a higher ultimate strength than concrete made with Portland cement.

Cao	30%-50%
Sio_2	28%-38%
Al_2O_3	8%-24%
Mgo	1%-18%

Table 1: Chemical Composition of GGBS

II. EXPERIMENTAL PROGRAMME

A. Parent Concrete

At first, the characteristics of materials Cement, Fine aggregate, Coarse aggregate are investigated. Ordinary Portland cement (OPC) of 53 grade, natural fine and natural coarse aggregates were used to produce Normal concrete. M35 grade is selected as Normal (or) Control Concrete and used to compare the properties of GGBS Concrete. The properties of cement, Fine aggregate and coarse aggregate are represented in Table II, Table III respectively.

S. No.	Particulars of test	Test Results	Requirement as per IS Code
1.	Specific gravity	3.15	-----
2.	Fineness	9%	10
3.	Standard Consistency	28%	26% - 33%
4.	Initial Setting time	35 minutes	Minimum – 30 Min.
5.	Final Setting time	435 minutes	Maximum – 600 Min.
6.	Compressive strength (28-Days)	52.5MPa	53.0MPa

Table 2: Properties of Cement

S. No.	Particulars of test	Aggregate		
		Fine aggregate	Coarse Aggregate	
			20mm	10mm
1.	Specific Gravity	2.63	2.72	2.76
2.	Water Absorption (%)	0.4	0.5	0.4
3.	Fineness Modulus	3.536	8.66	
4.	Bulk Density (Kg/m^3)	1449	1434	1525

Table 3: Properties of Natural Fine and Natural Coarse Aggregates

B. GGBS Concrete

Ground Granulated Blast Furnace Slag (GGBS) is collected from locally available sources. Cement is replaced with GGBS in various percentages such as 5, 10, 15, 20, 25, 30, 35 & 40 for the production of GGBS Concrete. IS 10262 – 2009 [3] is used for mix proportions. Normal mixing approach is adopted while mixing the materials. 150x150x150mm cubes were selected to investigate the hardened properties of GGBS Concrete [4]. The cubes were filled, compacted, cured and then tested for 7, 14 and 28 days. The Slump value is recorded

for every proportion. The mix proportions for Normal Concrete is represented in Table IV

S. No.	Name of the Component	Quantity (Kg/m^3)
1	Cement	376.133
2	Fine Aggregate	805.89
3	Coarse Aggregate	1087.27
4	Water	169.26

Table 4: Mix Proportions for Normal Concrete

III. Results and Discussions

A. *Workability of GGBS Concrete*

Workability is measured by slump cone test followed by IS 1199 – 1959 [5]. Workability of Concrete can be defined as the amount of energy to overcome friction while compacting or can also be defined as the relative ease with which concrete can be mixed, transported, moulded and compacted. From Figure I, it is observed that the workability of Normal concrete is around 55mm, Where as the workability of GGBS concrete ranges from 53 – 45mm. As GGBS particles absorb more water, the slump value is decreased with increase in GGBS content. Cement replaced with 5% GGBS achieves high workability than other percentages.

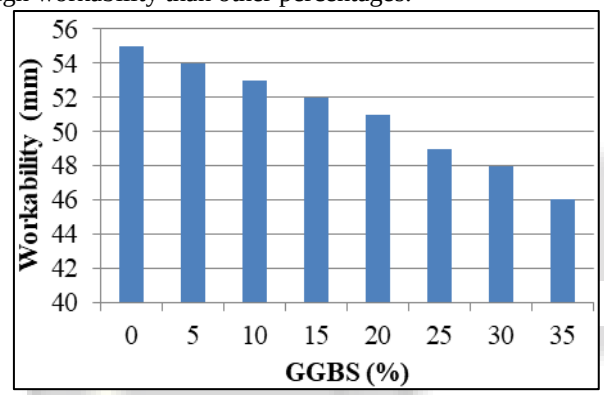

Fig. 1: Workability of Normal and GGBS Concrete

B. *Compressive Strength of Normal and GGBS Concrete*

The compressive strength of any material is defined as the resistance to failure under the action of compressive forces. Especially for concrete, compressive strength is an important parameter to determine the performance of the material during service conditions. Concrete mix can be designed or proportioned to obtain the required engineering and durability properties as required by the design engineer. The compression test was carried out as per IS 516 – 1959 [6] using compression testing machine of capacity 2000KN. The table V below represents the results of compressive strength of GGBS Concrete for 7, 14 and 28 days.

S.No.	GGBS (%)	Compressive Strength, MPa		
		7 Days	14 Days	28 Days
1	5	25.48	31.95	39.45
2	10	23.63	29.54	36.48
3	15	23.02	29.04	35.86
4	20	22.32	28.01	34.59
5	25	20.52	26.07	32.19
6	30	19.36	24.5	30.25
7	35	18.45	23.45	28.96
8	40	17.04	21.41	26.44

Table 5: Compressive strength of GGBS Concrete

From the above table, it is observed that Compressive strength of GGBS concrete is decreased with increase in GGBS percentage. Cement replaced with 5% GGBS has a higher compressive strength of 39.45 MPa, whereas with 40% GGBS has a lower compressive strength of 26.44 MPa. This implies that addition of GGBS to cement should be limited to some extent, i.e., 20% for M35 grade concrete.

IV. Conclusions

The following conclusions can be drawn from this study:

1) Workability of GGBS Concrete decreases with increase in percentage replacement of GGBS.
2) Compressive strength of GGBS Concrete increases with increase in age of curing.
3) Compressive strength of GGBS Concrete decreases with increase in percentage replacement of GGBS.
4) Compressive strength of GGBS Concrete with 5% replacement shows higher strength, compared to 40% replacement.

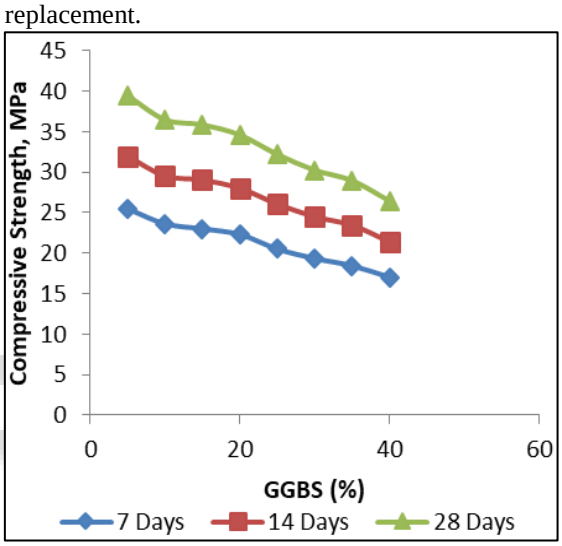

Fig. 2: Compressive Strength of GGBS Concrete

GGBS Concrete can achieve compressive strength of normal concrete.

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