Experimental Investigation of Granulated Blast Furnace Slag as Fine Aggregate in Concrete

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Abstract - *Concrete is a mixture of cement, aggregates and water which are economically available. Sand is a most important material used for preparation of mortar as well as concrete. In India, natural river sand (fine aggregate) is commonly used in mortar and concrete. Manufactured sand is somewhat different from natural river sand. The difference is that its surface characteristics are different from that of natural sand. Generally artificial sand is irregular and also it is more porous. Grading varies over a wide range which results in the internal porosity and reduction in workability of concrete.*

Key Words: *Aggregate, Slag, Blast, Furnace*

1. INTRODUCTION

Granulated blast furnace slag is a by-product of iron and steel which is produced in a blast furnace to produce a granular product. It can also be define as blast-furnace slag is a non-metallic product, which consists of silicates and aluminasilicates of calcium and other bases which can be developed in a molten condition with iron or steel in a blast furnace. Blast furnace slag as an aggregate in concrete provides environmental as well as economical benefits. Many steel industries in India are supplying GBFS as an alternative to sand.

1.1 Types of blast furnace slag

There are many types of blast furnace slag. First type of slag includes blast furnace rock slag which can be used as a coarse aggregate for the construction of buildings but mainly for road construction. It is well known as blast furnace rock slag. Molten slag after leaving the blast furnace is directed towards the ground bays where it air-cools the slag to form a rock like material. BFS is used for the building construction in the production of concrete used as an aggregate. It is also used in the road construction for the preparation of base and sub-base coarse. It can also be mixed with other materials for mechanically stabilizing as a cementitious material. When compacted, BFS develops a high degree of mechanical particle interlock which results in high shear strength partly due to its rough texture.

1.2 Appearance

GGBS after mixing with cement gives a very nice lighter white colour which gives a great advantage for the architectural view with low cost. To acquire such type of colour in concrete, GGBS content in cement should be from 50% to 70%. Adding GGBS in cement also produce a smooth surface due to which dirt does not adhere to the surface which reduces maintenance cost.

2. Objectives

1. To determine the optimum content of GBFS for the replacement of natural river sand.

2. To check the behaviour of concrete in compression, tension and flexure strength.

3. To study the effect of concrete using GBFS over conventional concrete.

3. Literature Review –

A. S. Al-Gahtani et al. (1994) studied a design for the evaluation of the relative corrosion of concrete produced by using Portland cements containing 2% to 14% C3A cement with and without 50%, 60%, 70%, and 80% cement replacement by blast-furnace slag (BFS).[1]

K. Ganesh Babu and V. Sree Rama Kumar (2000), makes an effort to check the efficiency of concrete at the age of 28 days using GGBS at various replacement levels. The GBFS cement is replaced in concrete in the percentage of 10% to 80%. For 28 days evaluation, the overall strength efficiency factor 'k' varies from 1.29 to 0.70 for the replacement of 10% to 80%. The overall strength of concrete varies in from of 20MPa to 100MPa by replacing GGBS 10 to 80% [2].

Gengying Li and Xiaohua Zhao (2003) presents a laboratory investigation by using the combination of fly ash (FA) and ground granulated blast furnace slag (GGBS) over the properties of high strength concrete.

Cengiz Duran Atis and Cahit Bilim (2007) reports a laboratory investigating the compressive strength of ground granulated blast furnace slag (GGBFS) of concrete carried under wet and dry curing conditions.

Isa Yuksel et al. (2007) presents an investigation over affecting the concrete durability by using bottom ash (BA), granulated blast furnace slag (GBFS), and combination of both of these materials as fine aggregate in cement concrete.

Isa Yuksel et al. (2007) discuss about the research which is aimed at studying the use of bottom ash (BA) and granulated blast-furnace slag (GBFS) in producing cement concrete elements. Concrete element includes briquettes; paving blocks and kerbs specimens containing GBFS and BA replacing fine aggregate were allowed to cast in the laboratory.

Okzan Sengul and Mehmet Ali Tasdemir (2009) investigate the compressive strength of concrete. Ordinary Portland cement is replaced partially by using finely ground granulated blast furnace slag and finely ground fly ash.

Juan Lizarazo Marriaga et al. (2011) presents an investigation on the compressive strength of concrete with the influence of steel basic oxygen slag (BOS) and ordinary Portland cement; along with that the hydration mechanism of ground granulated blast furnace slag (GGBS) pastes is also evaluated.

Rafat Siddique and Deepinder Kaur (2012) deal with the mechanical properties of concrete produced by using ground granulated blast furnace slag (GGBFS) which was subjected to temperatures up to 350ºC. For this purpose, concrete was designed for the compressive strength of 34 MPa using GGBFS as a partial replacement of cement. Cylindrical specimens of size 150 x 300 mm were casted and then they were subjected to elevated temperatures of 100ºC, 200ºC and 350ºC.

4. Methodology –

The experimental study was carried out in three phases. The first phase of the experiment was to check the compression strength on the cubes of the trial concrete mix which was necessary to adopt for mix design. The second phase includes preparing a concrete replacing natural river sand with different GBFS percentage to check on which GBFS percentage the maximum compression strength will achieve. The third phase includes adopting the proper variation to further split tensile test and flexure test.

1. A mix design for M25 grade of concrete is adopted for trial. Cubes were casted for curing period of 28 days. These cubes were tested for compression strength. By analysing the results the final mix design was adopted.

2. A total 9 number of cubes were casted replacing natural river sand by using GBFS by 30%, 40% and 50% in order to test the cube specimens for the maximum compression strength. By analysing results further replacements were done.

3. Further 9 cubes were casted by replacing Natural River sand using GBFS by using variations of 25%, 30% and 35% for the compression test. After the results these variations were adopted.

4. Further cylinder and beam were allowed to cast for the variation of 25%, 30% and 35. A total number of 12 cylinders and 12 beams were casted for split tensile test and flexure test respectively. After the test an optimum amount of GBFS as a fine aggregate was concluded.

Testing of specimen –

The details of testing in the experiment are stated below. The apparatus on which tests was conducted is given below.

Compression test is usually carried out with the ultimate aim of determining the compressive strength of hardened concrete at 28 days of curing age. For compression test, cube test of two types of specimens either cubes of 150mm x 150mm x 150mm or 100mm x 100mm x 100mm depending upon the size of aggregate are used. For most of the works cubical moulds of size 150mm x 150mm x 150mm are commonly used. This test is referred to as the greatest resistance of concrete cube to applied axial loading from the compression machine. Compressive strength test is conducted to determine the greatest resistance at failure of concrete cube samples to applied axial loading. These specimens are tested by compression testing machine after 28 days curing. Load should be applied gradually till the specimens fails. The compressive strength shall be average of the strengths of the three cubes for each variation respectively. Load at the failure divided by area of specimen gives the compressive strength of concrete.

Discussions -

The variations in GBFS percentage replacements show different results for all tests. The increase and decrease in strength as well as the load carrying capacity for different beams and their deflections are stated below.

Strength -

1. For the compression test, it has been observed that the maximum increase in the percentage of compressive stress with the control specimen is of 11.80% for 30% replacement of river sand. The decrease in the percentage of compressive stress with control specimen is found to be 18.64% for 25% replacement of river sand. Also there is a slight decrease in compressive stress of 9.96% for 50% replacement of river sand. Further increase in compressive stress for 35% and 40% replacement of sand is found to be 2.40% and 0.71%.

2. For split tensile test, the maximum increase in tensile strength was found out to be 22.64% for 30% replacement of river sand whereas decrease in tensile strength was of 36.47% for 25% replacement of river sand. Further increase

in tensile strength for 35% replacement of sand was found to be of 11.32%.

5. CONCLUSIONS

1. The maximum strength is obtained at 30% GBFS for the replacement of natural river sand. Hence the optimum content for replacement of sand is 30%.

2. In compression test, the maximum percentage increase is 11.80% more than that of control specimen in 30% replacement of GBFS. In split tensile test, the maximum tensile strength is on 30% replacement of GBFS than that of control specimen. The percentage increase was 22.64%. In flexure test 12.53% increase flexure strength is for 30% GBFS than control beam.

3. At first, the strength in concrete was increased by increasing the GBFS content at a level of 30% replacement. Later it goes on decreasing.

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