Experimental Study on Using Blast Furnace Slag As Replacement of Coarse Aggregate To Produce Self-Compacting Concrete

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Abstract- *Self-compacting concrete is a type of concrete that does not require external or internal compaction but it gets compacted under its self-weight. It is defined as the concrete which can be placed and compacted into every corner of a form work, purely by means of its self-weight by eliminating the need of vibration or any type of compacting effort. This concrete is highly flowable and cohesive enough to be handled without segregation. It is also referred as self-leveling concrete, super-workable concrete, highly-flowable concrete, non-vibrating concrete, etc. Abundant availability of natural resources has become a dream for present day engineering society due to large scale consumptions. To overcome the problem of scarcity of natural aggregates and to save the environment from the pollution due to dumping of slag, civil engineers opined that there is significance potential for reuse of slag for use in value added application to maximize economic and environment benefit. . In this study an experimental investigation has been carried out to study the significance of blast furnace slag as partial replacement for coarse aggregate in self-compacting concrete. Ground Granulated Blast Furnace Slag (GGBS) is a waste product from the iron manufacturing industry. Ground granulated blast furnace slag (GGBS), due to its pozzolonic nature, could be a great asset for the modern construction needs, because slag concretes can be of high performance, if appropriately designed. The investigation was carried out with workability tests such as slump flow test. The compressive strength and split tensile strength were also studied.*

Keywords- self-compacting concrete, blast furnace slag

I. INTRODUCTION

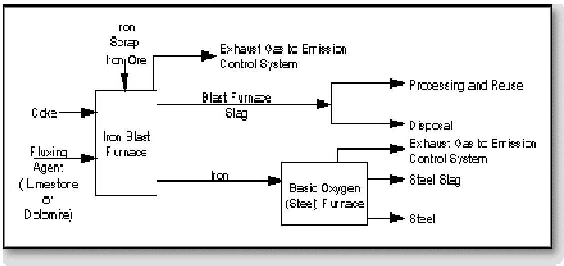
Self-compacting concrete (SCC) is a flowing concrete that does not require vibration and, indeed, should not be vibrated. It achieves compaction into every part of the mould or formwork simply by means of its own weight without any segregation of the coarse aggregate. It was originally developed in Japan, to overcome the problems caused by lack of complete and uniform compaction through vibrators. SCC affords quiet casting, and the environmental loadings from noise are therefore reduced. It also eliminates the issue of blood circulatory problems caused by the vibration of concrete. SCC offers:

- Health and safety benefits (as no vibration is required).
- Faster construction times.
- Increased workability and ease of flow around heavy reinforcement.
- Excellent durability.

Use of GGBS as cement replacement will simultaneously reduce cost of concrete and help to reduce rate of coarse aggregate consumption. Experts claim that „Granulated Blast Furnace Slag' is the best option among all. "Granulated Blast Furnace Slag is produced from the slag that forms during the production of steel. An American Foundry Society (AFS) study in Illinois investigated foundry sand as a substitute for coarse aggregate in concrete. When Granulated Blast Furnace Slag without fines replaced a portion of the coarse aggregate, the concrete produced had workability, compressive strengths, tensile strengths and modulus of elasticity values comparable to mixtures composed of coarse aggregate.

II. GROUND GRANULATED BLAST FURNACE SLAG AND ITS PROPERTY

2.1 In the production of iron, iron ore, iron scrap, and fluxes (limestone and/or dolomite) are charged into a blast furnace along with coke for fuel. The coke is combusted to produce carbon monoxide, which reduces the iron ore to a molten iron product. Blast furnace slag is a nonmetallic coproduct produced in the process. It consists primarily of silicates, aluminosilicates, and calcium-alumina-silicates. The molten slag, which absorbs much of the sulfur from the charge, comprises about 20 percent by mass of iron production. Figure 3-1 presents a general schematic, which depicts the blast furnace feedstocks and the production of blast furnace coproducts (iron and slag)



The main components of blast furnace slag are CaO, SiO_2, Al_2O_3, and MgO. In general increasing the CaO content of the slag results in raised slag basicity and an increase in compressive strength. The MgO and Al_2O_3 content show the same trend up to respectively 10-12% and 14%, beyond which no further improvement can be obtained. Several compositional ratios or so-called hydraulic indices have been used to correlate slag composition with hydraulic activity; the latter being mostly expressed as the binder compressive strength.

2.2 Physical Properties

Table-1 lists some typical physical properties of blast furnace slags.

Property	Value
Specific Gravity	2.0 - 2.5
Compacted Unit Weight, kg/m^3	1120 - 1360
Absorption (%)	1 - 6

Crushed ACBFS is angular, roughly cubical, and has textures ranging from rough, vesicular (porous) surfaces to glassy (smooth) surfaces with conchoidal fractures. There can, however, be considerable variability in the physical properties of blast furnace slag, depending on the iron production process.

2.3Chemical properties

Table-2 chemical properties of blast furnace slags.

Constituent	Percent	
	Mean	**Range**
Calcium Oxide (CaO)	**41**	34-48
Silicon Dioxide (SiO_2)	36	31-45
Aluminum Oxide (Al_2O_3)	**13**	10-17
Magnesium Oxide (MgO)	**7**	1-15
Iron (FeO or Fe_2O_3)	**.05**	0.1-1.0
Manganese Oxide (MnO)	**0.8**	0.1-1.4
Sulfur (S)	**1.5**	0.9-2.3

III. CONCRETE WITH BLAST FURNACE SLAG

3.1 In these research we replace coarse aggregate with blast furnace slag in different percentages.

Material used in the test concrete are:

The materials used were:

1- Cement: Ordinary Portland cement.
2- Sand: The river sand having a fineness modulus of 2.74 and specific gravity of 2.7 with good gradation.
3- Gravel: The gravel with maximum size of 9 mm and specific gravity equal to 2.72 from was used as coarse aggregate.
4 Blast furnace slag: The Blast furnace slag obtained from nearby steel industry was used to replace coarse aggregate
5- water: ordinary tap water.

3.2 mix proportion

The concrete is made by electric mixer. First sand coarse aggregate and blast furnace slag is dry mixed and after that cement and water is add to make concrete.

5 type of specimen are made.

Table 3 – various group of SCC

Group	Coarse
SCC0	Natural aggregate
SCC10	10% blast furnace slag replacement as coarse aggregate
SCC20	20% blast furnace slag replacement as coarse aggregate
SCC30	30% blast furnace slag replacement as coarse aggregate
SCC40	40% blast furnace slag replacement as coarse aggregate

IV. FRESH PROPERTY TEST

The slump test is a popular consistency test and is applied in the quality control testing of fresh concrete at construction sites and laboratory also. It is a well-known that the property of fresh concrete can be expressed approximately by Bingham's model with yield value and plastic viscosity.

Test apparatus:

The basic equipment used is the same as for the conventional Slump test4 (Figure 2).

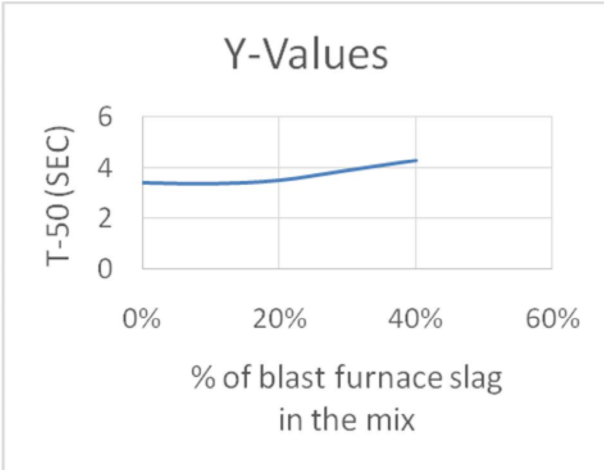
Test procedure:

Fill the sample in the cone. Concrete is filled in one continuous layer without rodding or vibrating. The horizontality shall be confirmed with a level. Prepare the sample in the receiving container and pour into the cone by evenly distributing the concrete over the area. Level the top surface of concrete with the top rim of the slump cone, and immediately raise the cone vertically by a steady upward lift without interruption. When the movement of the concrete has stopped, measure the apparently maximum diameter and the diameter at right angles to it, and take the average of both diameters as the slump flow. Simultaneously, start the stopwatch and record the time taken for the concrete to reach the 500mm spread circle. This is the T50 time.

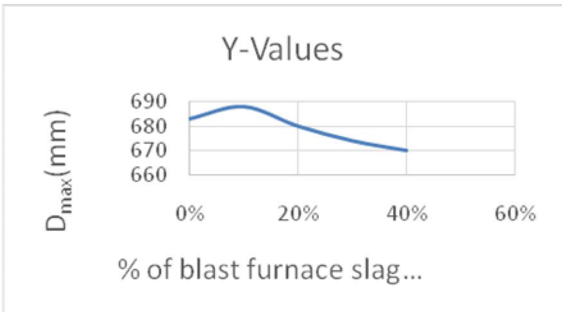
4.3 Result:

Table 4- slump flow test result

Group No.	% of blast furnace slag in the mix	SLUMP TEST	
		T-50 (SEC)	D_{max}(mm)
SCC0	0%	3.4	683
SCC10	10%	3.36	688
SCC20	20%	3.5	680
SCC30	30%	3.9	674
SCC40	40%	4.3	670



Graph 1 - % of blast furnace slag in the mixvsT-50 (SEC)



Graph 2- % of blast furnace slag in the mixvsD_{max}(mm)

V. HARDEN PROPERTY TEST

There are two test for harden property of concrete

1. Compressive strength test: for that cubes of size 100mm x 100mm x 100mm are cast and cured for 7 days and 28 days for test.
2. Tensile strength test: for that cylinder of size 100 mm x 200 mm are cast and cured for 7 days and 28 days for test.

5.1. Compressive strength test:

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. The strength of concrete is required to calculate the strength of the members. Concrete specimens are a cast and tested under the action of compressive loads to determine the strength of concrete. In very simple words, compressive strength is calculated by dividing the failure load with the area of application of load, usually after 28 days of curing

5.2. Procedure:

Specimens stored in water shall be tested immediately on removal from the water and while they are still in the wet condition. Surface water and grit shall be wiped off the specimens and any projecting find removed specimens when received dry shall be kept in water for 24 hours before they are taken for testing. The dimensions of the specimens to the nearest 0.2mm and their weight shall be noted before testing. Placing the specimen in the testing machine the bearing surface of the testing machine shall be wiped clean and any loose sand or other material removed from the surface of the specimen. Which are to be in contact with the compression platens. In the case of cubes the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is, not to the top and bottom. The load shall be applied without shock and increased continuously at a rate of approximately 140 kgfcm/min until the resistance of the specimen to the increasing load breaks down and no grater load can be sustained. The maximum load applied to the specimen shall then be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted.

Fig 3: compressive strength test

5.2. Tensile strength Test:

Tensile strength is an important property of concrete because concrete structures are highly vulnerable to tensile cracking due to various kinds of effects and applied loading itself. However, tensile strength of concrete is very low in compared to its compressive strength.one of the method for find tensile strength is split cylinder test.

Split-Cylinder Test

It is the standard test, to determine the tensile strength of concrete in an indirect way. This test could be performed in accordance with IS : 5816-1970.

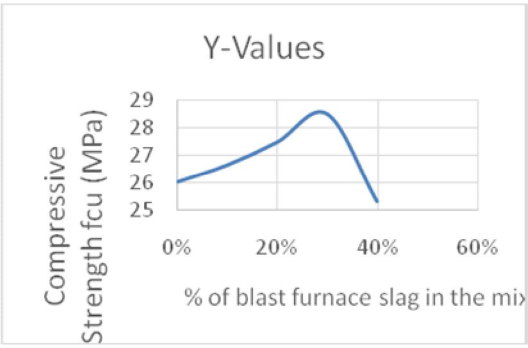
A standard test cylinder of concrete specimen is placed horizontally between the loading surfaces of Compression Testing Machine (Fig-4). The compression load is applied diametrically and uniformly along the length of cylinder until the failure of the cylinder along the vertical diameter. To allow the uniform distribution of this applied load and to reduce the magnitude of the high compressive stresses near the points of appplication of this load, strips of plywood are placed between the specimen and loading platens of the testing machine. Concrete cylinders split into two halves along this vertical plane due to indirect tensile stress generated by poisson's effect.

Fig 4:.split Tensile Test

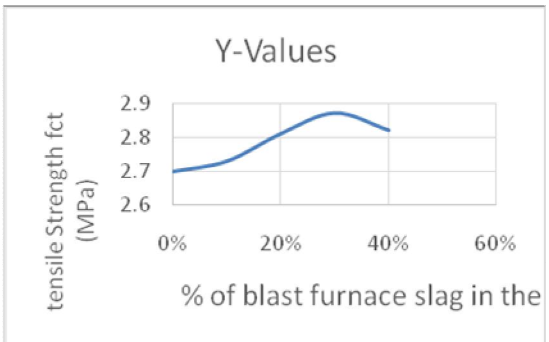
5.3 Result:

Table 5- result for Compressive Strength and tensile Strength

Type of specimen	% of blast furnace slag in the mix	Compressive Strength fcu (MPa)	tensile Strength fct (MPa)
SCC0	0%	26	2.7
SCC10	10%	26.62	2.73
SCC20	20%	27.46	2.81
SCC30	30%	28.49	2.87
SCC40	40%	25.28	2.82



Graph 3-% of blast furnace slag in the mixvsCompressive Strength



Graph 4 - % of blast furnace slag in the mixvs tensile Strength

VI. CONCLUSIONS

1. Concrete with blast furnace as a replacement of coarse aggregate gives satisfactory result.
2. workability of concrete with blast furnace slag increase upto 10% replacement of coarse aggregate as in slump flow test D_{max}value increase upto 10% and started decrease with replacing higher percentage and T-50 value decrease upto 10% and started increase in further more % replacement.
3. Compressive Strength of concrete with blast furnace slag increase upto 30% replacement of coarse aggregate.
4. Tensile Strength of concrete with blast furnace slag increase upto 30% replacement of coarse aggregate.

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