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# Study of Blast Furnace Slag for Improving Mechanical Property of Concrete

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**ABSTRACT:** *Due to growing environmental awareness, as well as stricter regulations on managing industrial waste, the world is increasingly turning to researching properties of industrial waste and finding solutions on using its valuable component parts so that those might be used as secondary raw material in other industrial branches. Although iron and steel slag is still today considered waste and is categorized in industrial waste catalogues in most countries in the world, it is most definitely not waste, neither by its physical and chemical properties nor according to data on its use as valuable material for different purposes. Moreover, since the earliest times of the discovery and development of processes of iron and other metals production, slag as by-product is used for satisfying diverse human needs, from the production of medicines and agro-technical agents to production of cement and construction elements. Considering the specificity of physical and chemical properties of metallurgical slags and a series of possibilities for their use in other industrial branches and in the field of civil constructions, this report demonstrates the possibilities of using iron slag as partial replacement of sand in concrete. Iron and steel making slag are by products of the iron making and steelmaking processes. To date, these types of slag have been widely used in cement and as aggregate for civil works. The report presents an investigation of mechanical and durability properties of concrete by adding iron slag as replacement of sand in various percentages.*

**KEYWORDS:** Blast Furnace Slag, Aggregate.

## I. INTRODUCTION

Concrete is a main constituent of the Civil Engineering structures. We cannot imagine the structures without concrete. It is becoming the backbone of infrastructural development of whole world. Concrete has capacity to enhance its properties with the help of other suitable constituents.

The main disadvantages of concrete are as follows -

- 1) Very low tensile strength
- 2) Brittleness
- 3) Less resistance to cracking
- 4) Heavy mass (density)
- 5) Shrinkage cracks

Some remedial measures can be taken to minimize some bitter properties of concrete. Waste is the one of the main challenges to dispose and manage. It has become one of the major environmental, economical and social issues. Recycling is the most promising waste management process for disposal of materials like agricultural waste and Industrial by-product like blast furnace slag, fly ash, silica fume, rice husk, phosphogypsum etc. The use of above mentioned waste products with concrete in partial amount replacing sand paved a role for

- 1) Modifying the properties of the concrete
- 2) Controlling the concrete production cost
- 3) The advantageous disposal of industrial waste.

The use of particular waste product will be economically advantageous usually at the places of abundant availability and production.

## II. BLAST FURNACE SLAG

Blast furnace slag is a nonmetallic by-product produced in the process of iron making (pig iron) in a blast furnace and 300kg of Blast furnace slag is generated when 1 ton of pig iron produced. In India, annual productions of pig iron is 70-80 million tons and corresponding blast furnace slag are about 21-24 million tons. Blast furnace slag is mildly alkaline and exhibits a pH in solution in the range of 8 to 10 and does not present a corrosion risk to steel in pilings or to steel embedded in concrete made with blast furnace slag cement or aggregates. The blast furnace slag could be used for the cement raw material, the roadbed material, the mineral admixture for concrete and aggregate for concrete, etc. Now in India, resources of natural sand are very lacking, it is necessary that the new fine aggregate was sought. The property of blast furnace slag is similar to natural sand, the price is cheap and the output is large too, could be regarded as the substitute of the natural sand. But



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there is no experience about application of blast furnace slag fine aggregate in concrete and the reports about the research are also few. In this investigation a series of experiments about mechanical characteristics of concrete using ground granulated blast slag (GGBS) fine aggregate would be done, and results of investigation on compressive strength, tensile strength and properties of fresh concrete could be reported.

### III. APPLICATIONS

GGBS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials. GGBS has been widely used in Europe, and increasingly in the United States and in Asia (particularly in Japan and Singapore) for its superiority in concrete durability, extending the lifespan of buildings from fifty years to a hundred years.

Two major uses of GGBS are in the production of quality-improved slag cement, namely Portland Blast furnace cement (PBFC) and high-slag blast-furnace cement (HSBFC), with GGBS content ranging typically from 30 to 70%; and in the production of ready-mixed or site-batched durable concrete.

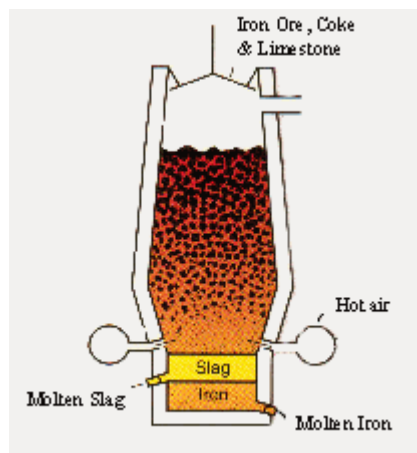
Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBS in the cementitious material, but also continues to gain strength over a longer period in production conditions. This results in lower heat of hydration and lower temperature rises, and makes avoiding cold joints easier, but may also affect construction schedules where quick setting is required.

#### *How GGBS cement is used*

GGBS cement is added to concrete in the concrete manufacturer's batching plant, along with Portland cement, aggregates and water. The normal ratios of aggregates and water to cementitious material in the mix remain unchanged. GGBS is used as a direct replacement for Portland cement, on a one-to-one basis by weight. Replacement levels for GGBS vary from 30% to up to 85%. Typically 40 to 50% is used in most instances. The use of GGBS cement in concrete in Ireland is covered in the new Irish concrete standard IS EN 206-1:2002. This standard establishes two categories of additions to concrete along with ordinary Portland cement: nearly inert additions (Type I) and pozzolanic or latent hydraulic additions (Type II). GGBS cement falls in to the latter category. As GGBS cement is slightly less expensive than Portland cement, concrete made with GGBS cement will be similarly priced to that made with ordinary Portland cement.

#### *What is GGBS?*

Ground granulated blast furnace slag (GGBS) is a by-product from the blast-furnaces used to make iron. These operate at a temperature of about 1,500 degrees centigrade and are fed with a carefully controlled mixture of iron-ore, coke and limestone. The iron ore is reduced to iron and the remaining materials form a slag that floats on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching optimises the cementitious properties and produces granules similar to coarse sand. This 'granulated' slag is then dried and ground to a fine powder.





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TYPICAL CHEMICAL COMPOSITION		TYPICAL PHYSICAL PROPERTIES	
Calcium oxide	40%	Colour	off-white
Silica	35%	Specific gravity	2.9
Alumina	13%	Bulk density	1200 kg/m <sup>3</sup>
Magnesia	8%	Fineness	>350m <sup>2</sup> /kg

**GGBS (Ground Granulated Blast Furnace Slag):**

It is a glassy granular material formed in the process of producing iron in a blast furnace and is formed by rapidly chilling or quenching the molten material and subsequently grinding it to a fine powder. The properties of GGBS were shown in Table 2 (It was supplied by Andhra cement ltd.).

**Table-2 properties of GGBS**

1	Fineness	3.12
2	Soundness	1.00mm
3	Initial setting time	260minutes
4	Insoluble residues	0.15% of mass
5	Magnesia content	9.47 % of mass
6	Sulphide sulphur	0.63 % of mass
7	Sulphide content	0.23 % of mass
8	Loss on ignition	0.30 % of mass
9	Magnesia content	0.30 % of mass
10	Glass content % optical microscopy	90.00 % of mass

**Table3-Test on Blast Furnace Slag  
Test Results (Anacon lab)**

S.No.	Test Parameters	Results
1	Calcium Oxide (CaO)	1.84
2	Silicon Dioxide (SiO <sub>2</sub> )	6.03
3	Aluminum Oxide (Al <sub>2</sub> O <sub>3</sub> )	2.28
4	Magnesium Oxide (MgO)	0.47
5	Iron (Fe <sub>2</sub> O <sub>3</sub> )	83.51
6	Manganese Oxide (MnO)	0.63
7	Sulfur (S)	0.04
8	Phosphorous Pentoxide (P <sub>2</sub> O <sub>5</sub> )	0.31
9	Chromium Oxide (Cr <sub>2</sub> O <sub>3</sub> )	0.06

**IV. LITERATURE REVIEW**

- 1) Chetan+thesis.Pdf-Adobe Reader
- 2) Case study \_blast\_furnace\_slag(3). Pdf-Adobe Reader
- 3) [http://en.wikipedia.org/wiki/Ground\\_granulated\\_blast\\_furnace\\_slag](http://en.wikipedia.org/wiki/Ground_granulated_blast_furnace_slag)
- 4) Anacon Labs Pvt. Ltd , ISO 9001:2008 Certified Organization, Outward No. AN/W/2012-13/350
- 5) Dongsheng Shi, Yashihiro Masuda and Youngaran Lee, *Advanced Materials Research (2011)*

In their experimental study the potential use of blast furnace slag fine aggregate was that produced by 3 different steel factory in high strength concrete and mechanical properties of high strength concrete were studied. The concrete using the blast furnace slag fine aggregate is admitted the increase of compressive strength as well as the case of the river sand when the water cement ratio is reduced, and the compressive strength can attain 100N/mm<sup>2</sup>. The strength of concrete using blast furnace slag fine aggregate is lower than the strength of concrete using natural river sand as fine aggregate, and the strength of concrete using mixture fine aggregate is



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middle of strength used river sand and strength used blast furnace slag fine aggregate. The crushing values of blast furnace slag fine aggregate is bigger than the natural river sand, and it could influence the strength concrete using blast furnace slag fine aggregate.

**6) Maria Arm, experimental tests on MSWI bottom ash, crushed concrete and blast furnace Slag, Stockholm, Sweden 2003**

For recycled aggregates and industrial by-products to be used correctly in road construction, it is necessary to know their properties. The objective of this thesis is to increase knowledge of the mechanical properties of certain selected residues for improved design of pavements using these residues. This study has concentrated on residues in unbound road layers. The materials selected were processed crushed concrete and air-cooled blast furnace slag (AcBFS), municipal solid waste incinerator (MSWI) bottom ash. The results were compared with those of the conventional aggregates they could possibly replace, such as sand, gravel and crushed rock. The laboratory results showed that a high content of unburned material in MSWI bottom ash limits the resilient modulus but not the permanent deformation to the same extent. Both laboratory and field results showed several years growth in stiffness for unbound layers with crush concrete and Air cooled Blast Furnace Slag, which is not present for unbound layers with natural aggregates.

**7) Venu Malagavelli et. al. / International Journal of Engineering Science and Technology (2010)**

In this paper focuses on investigating characteristics of M30 concrete with partial replacement of cement with Ground Granulated Blastfurnace Slag (GGBS) and sand with the ROBO sand (crusher dust). The cubes and cylinders are tested for both compressive and tensile strengths. It is found that by the partial replacement of cement with GGBS and sand with ROBO sand helped in improving the strength of the concrete substantially compared to normal mix concrete.

**8) David N. Richardson, Organizational Results Research Report, Missouri Transportation**

In the investigation reported in this paper, for a bridge pier and abutment mass concrete project, three mixes were studied: an ordinary Portland cement (OPC) mix (Type I PC) and two 70% by weight ground granulated blast furnace slag (GGBS) mixes (Type II Low Heat PC). One of the slag mixes contained a high range water reducer (HRWR) and tests for compressive strength, freeze thaw durability, etc. It was concluded that although the optimum blast furnace slag proportion for strength was 50%, blast furnace slag replacement levels of up to 70% could be used to achieve moderate strength levels. Strength parity with zero slag mixes is possible with 70 % slag under proper conditions, which include sufficient activity of the slag-PC system.

**9) Naoual Handel, J. Mater. Environ. Sci. 2 (S1) (2011)**

In this study we sought to use the Crushed Crystallized slag of blast furnace. It is used as aggregate in preparing slag concrete filling of steel columns. It is produce by totally or partially replacing the calcareous gravel by Crushed Crystallized slag of blast furnace. The study is comparison between slag concrete and ordinary concrete. The characterization of these concretes was made based on their mechanical properties: i.e., compressive strength, tensile strength and elastic modulus, and their durability. The experimental results showed a beneficial effect is bound-up by the percentage of slag used in concrete.

**10) Wang Ling, Tian Pei, and Yao Yan, International Workshop on Sustainable Development and Concrete Technology**

In their studies the application of ground granulated blast furnace slag (GGBS) in China. The performance of GGBS is measured and the effect of GGBS on fresh concrete and harden concrete is analyzed. GGBS concrete is characterized by high strength, lower heat of hydration, and resistance to chemical corrosion. When used in concrete, it make concrete has good workability, high strength, and good durability. GBFS is a kind of industry waste. Through advanced processing technology, the material turns into GGBFS, which can act as an economical and ecological resource for modern concrete. Research, production and application of GGBFS in HPC promote the comprehensive utilization of slag into a new stage in China.

**11) Ing Lim, Jenn-Chuan Chern, Tony Liu, and Yin-Wen Chan , "Journal of Marine Science and Technology ", (2012)**

In his experimental study examines the effect of using Ground Granulated Blast Furnace slag (GGBS) as partial cement replacement in producing engineered cementations composite (ECC). Slag replacement is not only to



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increase the strength but also to create better fiber bridging property that results in better ductility of the material. Amount of slag replacement and slag fineness are the variables involved in the mixture proportions.

**12) Lim, Siong Kang, Ling, Tung-Chai, Hussin, Mohd Warid: "ACI Materials Journal", (2011)**

This paper examines the possibility of using ground-granulated blast-furnace slag (GGBFS) as a partial replacement of filler in polymer grout. In this study, river sand was replaced by GGBFS at levels of 0 (control), 10, 20, and 30% by weight. The effects of 5 curing conditions on compressive strength at the ages of 7, 28, 90, 180, and 365 days were studied.

**13) Isa Yuksel, Omer Ozkan, and Turhan Bilir," Materials Journal", (2006)**

This paper reports the results of some experimental studies on the use of ground-granulated blast-furnace slag (GGBFS) as fine aggregate in concrete. Two groups of concrete samples were produced. The GGBFS/sand ratios were 0% (reference), 25, 50, 75, and 100%. The first group (C1) contains only 0 to 7 mm (0 to 0.276 in.) sand as fine aggregate. The second group (C2) contains two sub-types of fine aggregates that are 0 to 3 mm (0 to 0.118 in.) and 0 to 7 mm (0 to 0.276 in.) sands. GGBFS replaces 0 to 7 mm (0 to 0.276 in.) sand in both groups. Strength and durability characteristics of concrete were compared with respect to control samples and vice versa.

**14) Takashi Miura and Ichiro Iwaki "Materials Journal", (2000)**

In their experimental study presents the effect of mixture proportions and curing method on the strength development of concrete incorporating high levels of ground granulated blast-furnace slag (GGBS) at low temperatures. In this study, the strength development of mortar specimens incorporating GGBS for various mixture proportions and curing methods is investigated.

## V. CONCLUSION

Blast furnace slags can be used as partial replacement of cement as well as sand. Thus blast furnace slags are to be used as fine aggregates although they are used increasingly as a cement admixture because this use has a higher value. Blast furnace slag is nonreactive in a high alkali environment, such as concrete and soils. Blast furnace slag concrete can be reliably pumped when the slag is supplied to the ready-mix production in a saturated condition.

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