International Journal of Engineering, Science and Mathematics
Vol. 6 Issue 8, December 2017 (Special Issue)
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

# EFFECT ON COMPRESSIVE STRENGTH OF CONCRETE BY PARTIAL REPLACEMENT OF FINE AGGREGATE WITH BLAST FURNACE SLAG

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**Abstract**

The iron industries produce a huge quantity of blast furnace slag as by-product, which is a non-biodegradable waste material from that only a small percentage of it is used by cement industries to manufacture cement. In present inspection Blast Furnace Slag from Vizag-Steel Plant has been utilized for finding its appropriateness as a Fine Aggregate in concrete. Replacement of some natural aggregates with Slag would lead to abundant environmental benefits. It is interesting that the Blast Furnace Slag (BFS) can be used as a fine aggregate in concrete. Based on overall experimental results, it could be advisable that the Slag could be effectively utilized as fine aggregate in concrete practice.

***Keywords:***

Blast Furnace Slag (BFS);
Fine Aggregate;
Concrete;
Environmental benefits;
Compressive Strength;
Slag Aggregate;
Iron Industries;

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## 1. Introduction

Concrete is a composite material laid-back of granular materials like coarse aggregates embedded in a matrix and cased together with cement or binder which fills the spaces between the particles and fix them as one. To meet the planetary challenge of concrete in the future, it is becoming a more demanding task to find suitable alternatives for natural aggregates in preparation of concrete. Therefore the use of mutually exclusive sources for natural aggregates is becoming more frequent. Slag is a co-product of the iron production process. Iron cannot be prepared in the blast furnace without the production of its co-product i.e. blast furnace slag The use of blast furnace slag aggregates in concrete by replacing natural aggregates is a most promising concept because its impact strength is more than the natural aggregate. Steel slag aggregates are already being cast-off as aggregates in asphalt paving road mixes due to their mechanical strength, stiffness, porosity, wear resistance and water absorption capacity. Blast furnace slag, which is a by-product of iron making process, has a high $SiO_2$ content and hence at speed cooled blast-furnace slag, has an irregular structure and pozzolonic properties. According to Indian minerals yearbook 2011, blast furnace slag generation was estimated about 10 million tones range in India and approximately 15 to 40% of the total slag was utilized. Traditionally unappropriated slag is stock piled in the steel plants, and finally land filled at slag disposal sites. Since the current methods of accumulating and land filling are not conceivable, disposal of slag has become a significant concern both to slag processor companies and to environmental agencies in the last decades. Sustainability of blast furnace slag in civil engineering applications will not only assuage the slag disposal problem but also will offer a cost -effective substitute for conventional materials. In order to identify new applications for blast furnace slag in the construction industry, there is a significant need to characterize blast furnace slag, and to determine their engineering properties. The proper use of waste materials radically affects our economy and environment. The rapid growth of industrialization gave birth to voluminous kinds of waste by products which are environmentally hazard and create obstacles of storage. The construction industry has always been at leading edge in consuming these waste products. The consumption of Slag which is waste reproduced by steel industry, in concrete not only helps in diminishing greenhouse gases but also helps in making eco-friendly material. During the production of iron and steel, fluxes (limestone and/or dolomite) are charged into blast furnace along with coke for fuel.

**Necessity of the work**:

The development of concrete technology has been a gradual process over many years. Concrete, often being called the universal construction material has become an indispensable material of construction and is now used in greater quantities than other man made material. The need to develop cost effective and energy efficient building materials is self-evident in the present phase of increasingly scare and expansive traditional building materials. Therefore, appraising preferred industrial wastes for civil engineering construction is encouraged by many countries. Using industrial wastes helps conserve natural materials, brings about a pollution free environment as well as reduces cost of construction. Indeed the use of blast furnace slag as aggregates has been increasing in India in the last few years. Given the scarcity and high cost of naturally available aggregates, the importance of finding an alternative to natural aggregate need not be overemphasized. This exercise therefore deals with studying the performance of concrete by replacing, the conventional fine aggregates with blast furnace slag aggregates.

- **Objective of the work:**

The objective of the experimental investigation is basically:

To obtain the proportion of slag in fine aggregates that would give useful concrete for certain structural applications.

To realize the objective, an experimental study was made. The fine aggregates used were: (a) 100% river sand (b) a mix of 90% fine aggregates & 10% of blast furnace slag, (c) a mix of 80% fine aggregates & 20% of blast furnace slag, (d) a mix of 70% fine aggregates & 30% of blast furnace slag, (e) a mix of 60% fine aggregates & 40% of blast furnace slag, (f) a mix of 50% fine aggregates &50% of blast furnace slag, in concrete mix with coarse aggregates and ordinary Portland cement.

- **Scope of the work**:

Considering the strength as well as economy, the use of 1:1.84:2.96 ($M_{20}$ grade of concrete) of design mix has been adopted for this investigation. The mixes with different proportions of blast furnace slag and slag as fine aggregates have been studied. The proportion of the blast furnace slag and sand were ascertained using experimental results and literature information.

## 2. Methodology

The basic objective of this study was to identify substitute source of good quality aggregates which is depleting very fast due to the fast pace of construction activities in India. Use of blast furnace slag, a waste industrial by-product of iron and steel production contributes great opportunity to utilize as an alternative to naturally available aggregates. The blast furnace slag (BFS) is a waste of industrial material, it is relatively more recent pozzolonic material that has received extensive attention in both research and application.

The materials required for the concrete mix were collected from different sources. Then those materials were tested to know all the properties of materials.

The present investigation has been undertaken to study the effect of blast furnace slag on the mechanical properties of concrete, when fine-aggregates is replaced by blast furnace slag in different percentages i.e. 0%, 10%, 20%, 30%, 40%, 50%. The main parameter investigated was concrete compressive strength. The tests were conducted on M20 grade of concrete with a water cement ratio 0.50.

In this study, M20 grade of concrete mix was done as per IS: 10262-2009. In this mix design constant water cement ratio of 0.50 with targeted slump of 25-75mm by the replacement of 0%, 10%, 20%, 30%, 40%, & 50% of fine aggregate with blast furnace slag was maintained.

Based on the design mix the concrete mix is prepared, slump cone test & compaction factor test was conducted on fresh concrete for knowing workability of concrete. Specimens of dimensions 150mm x 150mm x 150mm cubes for compressive strength were casted.

A total number of 36 specimens were to be casted, out of which 18 specimens for 7 days & remaining 18 for 28 days for each 10% increase of blast furnace slag should be casted to study the corresponding compressive strength.

All the cubes casted will be cured for 7 days & 28 days with placing an identity mark on each cube for identity in a curing tank. All the cubes after completion of curing period will be test for its compression strength.

## 3. Materials Used

- **Cement**

  Ordinary Portland cement (Ramco 53 Grade) confirming to IS: 269-1976 was used throughout the investigation. Different tests were performed on the cement to ensure that it confirms to the requirements of the IS specifications.

  Fineness (%): 2
  Specific Gravity: 2.99
  Consistency (%): 29
  Initial & Final Setting Time (min.): 35 & 165

- **Aggregates**
  - Coarse Aggregates (Natural)

    Locally available stone chips were used for preparation of concrete. Machines crushed locally available hard rock, were graded 20mm and down size were used.

    Specific Gravity: 2.81
    Fineness Modulus (%): 1.81
    Bulk Density (Loose & Compacted): 1.612&1.864
    Moisture content (%): 0.3

  - Fine Aggregates (Sand)

    Locally available river sand passing through 4.75mm sieve as per IS: 383 provisions were used as fine aggregates.

    Specific Gravity: 2.60
    Fineness Modulus: 2.91
    Free Moisture Content: 0.15
    Bulking Of Sand (%): 18
    Bulk Density (Loose & Compacted): 1.64&1.78

    - Non-natural aggregates:

      This category consists of aggregates that are unnatural in origin. The reasons for their approach in concrete construction are:

      i. Environmental considerations are increasingly affecting the supply of non-natural aggregate.
      ii. There are strong objections to opening of pits as well as to quarrying.
      iii. At the same time, there are problems with the disposal of construction demolished waste & with dumping of domestic waste.

    - Ground Granulated Blast Furnace Slag:

      When the blast furnace is tapped to release the molten iron, it flows from the furnace with molten slag floating on its upper surface. These two materials are separated using a weir, the molten iron being channeled to a holding vessel and the molten slag to point where it is to be treated further. The final form of the blast furnace slag is dependent on the method of cooling. There are four main types of blast furnace slag: granulated, air cooled, expanded and pelletized.

      Blast furnace slag is a non-metallic by-product produced in the iron making process. It consists primarily of silicates, alumina-silicates, and calcium-alumina-silicates. The molten slag, which absorbs much of the sulphur forms the charges, comprises about 20% by mass of iron production. Different forms of slag product are produced depending on the method used to cool the molten slag. The blast furnace slag used in the work was procured from Vizag steel plant, Visakhapatnam. Fineness modulus of the blast furnace slag used in the work is 2.98. Specific gravity of blast furnace slag used is 2.59.

Photograph No.1**: GGBFS collected from VSP Steel Plant**

Specific Gravity: 2.59
Fineness Modulus (%): 2.98
Free Moisture Content: 0.10
Bulking Of Sand (%): 16
Bulk Density: 1.38

Referring to 600 micron sieve, the percentage passing is 58% which confirm that fine aggregate belongs to Zone-II as per IS:383-1970.

- **Water**

## 4. Mix Proportion

M20 Concrete Design proportions of OPC 53 grade:

| Mix | Cement | Fine-Aggregate | | Coarse-aggregate | | Water |
|---|---|---|---|---|---|---|
| | | Sand | BFS | 20mm | 10mm | |
| **M1(kg)** | 8.58 | 15.28 | 0 | 15.26 | 10.17 | 4.32 |
| **M2(kg)** | 8.58 | 13.75 | 1.53 | 15.26 | 10.17 | 4.32 |
| **M3(kg)** | 8.58 | 12.22 | 3.06 | 15.26 | 10.17 | 4.32 |
| **M4(kg)** | 8.58 | 10.69 | 4.59 | 15.26 | 10.17 | 4.32 |
| **M5(kg)** | 8.58 | 9.16 | 6.12 | 15.26 | 10.17 | 4.32 |
| **M6(kg)** | 8.58 | 7.65 | 7.65 | 15.26 | 10.17 | 4.32 |

Table No.1: Mix Proportions of M20 grade concrete with %replacement of BFS to Fine Aggregates

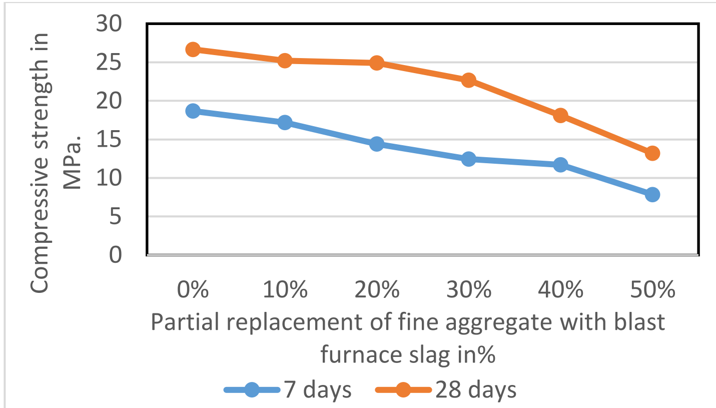
## 5. Results & Discussions

Compressive strength of the concrete design mix was checked by casting and testing of cubes (size 150mm$^3$) after the curing period of 7days & 28 days.

| No. | % replacement of BFS to F.A. | Slump | Compaction Factor | Compressive Strength (MPa) | |
|---|---|---|---|---|---|
| | | | | 7days | 28days |
| **M1** | 0 | 37 | 0.92 | 18.67 | 26.67 |
| **M2** | 10 | 39 | 0.97 | 17.19 | 25.18 |
| **M3** | 20 | 40 | 0.92 | 14.41 | 24.93 |
| **M4** | 30 | 41 | 0.94 | 12.44 | 22.66 |
| **M5** | 40 | 43 | 0.88 | 11.70 | 18.08 |
| **M6** | 50 | 45 | 0.94 | 7.85 | 13.20 |

Table No.2: Compressive Strength of Different Concrete Mixes

## 6. Conclusions




Graph No.1:Comparison of compressive strength of concrete for different percentages of blast furnace slag for 7 days & 28 days

By observing the results obtained from the different mixes, observed that the strength of the control specimen is more than that of the specimens which are prepared using the blast furnace slag.

It is identified that waste used here can be disposed by using them as construction materials.

Cubes with 10% to 30% GGBFS replacement of fine aggregates had given requisite strength of 22.67N/mm$^2$. Hence it can be used with proportions varying from 10%-30% replacement.

Waste and recycling management plans should be developed in order to sustain environmental, economic and social development of nation.The strength is comparatively decreasing with increase in percentage of partial replacement.

The replacement of fine-aggregate with blast furnace slag up to 30% can be used.

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