# Experimental Study on Optimization of Cement by Using Ground Granulated Blast Furnace Slag (GGBS) and M-Sand in High Performance Concrete

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***Abstract*- To reduce the carbon footprint on the environment and to reduce the optimum use of OPC by replacing with GGBS, an industrial waste with cost benefit. The OPC partially replaced with GGBS and the properties were observed using M50 concrete with various percentages of cement viz.. 40%, 45%, 50%, 55%, 60%, 65% & 70% as per Cl 18.4. of IRC 112.2011. Since River sand is becoming scarce nowadays, the use of manufactured stone (M-Sand) in concrete has become unavoidable. Hence properties of concrete using M-Sand with various percentages of GGBS replacement were tested and the results were compared. The 7th and 28th day test results indicate that the workability of concrete viz 40%, 45%, 50%, 55%, 60%, 65% & 70% replacement of cement by GGBS were excellent in High Performance Concrete (M50) and it is increased from 25 % to 68% compared to conventional concrete. The flexural strength and compressive strength were analysed in this study.**

***Index terms*- HPC – High Performance Concrete, GGBS – Ground Granulated Blast Furnace Slag, M-Sand – Manufactured Sand, Tensile strength, flexural strength & workability**

## I.INTRODUCTION

Concrete plays a vital role in the infrastructure development. Rapid increase in the consumption of concrete, the demand for cement has increased manifold. The cement industry is facing unprecedented challenges such as CO2 emissions and the need for alternative material is unavoidable. One ton of CO2 is released into the atmosphere for everyone ton of ordinary Portland cement (OPC) produced. This adds to the greenhouse gases which leads to global warming climate changes and other environmental degradations. Pressure over the construction industry and concrete technologists to reduce the consumption of cement by incorporating supplementary Cementitious materials and chemical admixtures in concrete. The concrete thus developed keeping the environment in mind is known as sustainable concrete.

GGBS (Ground Granulated Blast Furnace Slag) is a byproduct during the manufacture of iron in blast furnace. It is available in large quantities and occupies a lot of space. It is glassy and when dried granulated and ground it exhibits chemical properties similar to cement. This facilitates the use of GGBS as partial replacement of cement. Hence GGBS replaced cement can be used in combination with M-Sand comfortably. The other advantages are that the GGBS replaced cement produces low heat, protects concrete from chloride and sulphate attack.

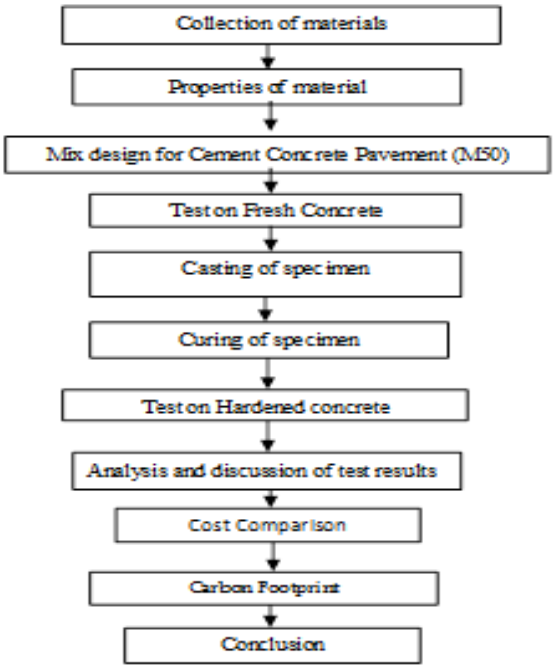
The aim of this research is to study the properties of M50 concrete with optimum partial replacement of cement with GGBS. Studies have been conducted by using GGBS and M-Sand and the results are compared to arrive at the right proportion.

## II. EXPERIMENTAL PROGRAM

### A. Objectives

- To study the strength parameters of the GGBS.
- To study the alternate material for Cement.
- To identify the potential use of GGBS
- To reduce carbon footprint using GGBS

### B. Methodology




## III. MATERIALS USED

Cement

Ordinary Portland cement of 53 grade was used for this research. The physical, chemical properties and compressive strength of the cement were tested and are given in the Tables 1, 2 and 3. The cement content used for all the concrete mixes was 450 kg/m3.

Table 1: Physical properties of Cement

| Physical Properties | Values | Requirement as per IS 269-2015 |
|---|---|---|
| Specific Gravity | 3.15 | _ |
| Specific surface (Air permeability test) | 270.80 $m^2$/kg | Min. 225 $m^2$/kg |
| Initial Setting Time | 120 minutes | Min. 30 mins |
| Final Setting Time | 265 minutes | Max. 600 mins |
| Soundness (Le Chatelier test) | 1 mm | Max. 10 mm |

Table 2: Chemical composition of Cement

| Constituents | Cement Clinker |
|---|---|
| Cao | 60-62% |
| Sio2 | 17-24% |
| Al2o3 | 3-7% |
| Fe2o3 | 0.5-0.6% |
| Mgo | 0.1-0.4% |

Table 3: Compressive Strength of Cement

| Age of Cement mortar cube | Compressive Strength | Requirement as per IS 269-2015 |
|---|---|---|
| 3 days | 24.01 MPa | Min. 23 MPa |
| 7 days | 34.35 MPa | Min. 33 MPa |
| 28 days | 45.69 MPa | Min. 43 MPa |

Fine Aggregate

Manufactured Sand (M-Sand) was used as fine aggregate for the research study. The specific gravity of M-Sand was 2.540. The sieve analysis test was conducted on fine aggregate. The fine aggregate fall in the grading limits for Zone - II as per IS: 383 as given in Table 4.

| Sieve size (mm) | Percentage Passing (%) | Percentage passing limits for Zone-II as per IS:383:2016 |
|---|---|---|
| 4.75 mm | 100.00 | 90 - 100 |
| 2.36 mm | 93.47 | 75 – 100 |
| 1.18 mm | 66.60 | 55 – 90 |
| 600 microns | 49.14 | 35 – 59 |
| 300micron | 27.62 | 8 – 30 |
| 150 microns | 7.58 | 0 – 10 |

Coarse Aggregate

Graded aggregates of manufactured hard blue granite of ISS 20 mm was used as coarse aggregate. The specific gravity of coarse aggregate was 2.674. The sieve analysis test was conducted on the coarse aggregate. The coarse aggregate fall in the grading limits as per IS 383-2016 as given in Table 5.

Table 5: Sieve analysis of coarse aggregate

| Sieve size (mm) | Percentage Passing (%) | Percentage passing limits as per IS 383-2016 (%) |
|---|---|---|
| 40 mm | 100 | 100 |
| 20 mm | 97.33 | 90-100 |
| 10 mm | 29.52 | 25-55 |
| 4.75 mm | 1.25 | 0-10 |

Other Physical tests for coarse aggregate such as Water absorption, Impact test and Crushing Strength test were conducted, and the results are given in Table 6.

Table 6: Physical properties of coarse aggregate

| Physical properties | Values | Max.Limits as per IS: 383:2016 |
|---|---|---|
| Water absorption | 0.40 % | 2% |
| Impact value | 17.50 % | 30 % |
| Crushing value | 21.50 % | 30 % |

Water

Potable water was used in the preparation of concrete mixes. Water - Cement ratio for all the mix

proportions was fixed to achieve adequate workability (slump) of fresh concrete.

GGBS:

Ground granulated blast furnace slag (GGBS) is one of the "greenest" of construction materials. Its only raw material is a very specific slag that is a byproduct from the blast furnaces manufacturing iron. The physical properties and chemical composition of GGBS were tested and given in table 7 and 8.

Table 7: Physical properties of GGBS

| Physical Properties | Values | Requirement as per IS 12089 |
|---|---|---|
| Specific Gravity | 2.89 | - |
| Specific surface (Air permeability test) | 320.00 $m^2/kg$ | Minimum 300 $m^2/kg$ |

Table 8: Chemical composition of GGBS

| Constituents | Cement Clinker |
|---|---|
| Cao | 34-43% |
| Sio2 | 27-38% |
| Al2o3 | 7-12% |
| Fe2o3 | 0.2-1.6% |
| Mgo | 7-15% |

Chemical Admixture:

To impart additional workability, Conplast SP430 super plasticizing chemical admixture was used in concrete for workability. Based on trial & error method, the optimum percentage of Super Plasticizer was found at 0.8% by weight of cement was used as given in Table No. 9.

Table No. 9. Properties of Chemical Admixture

| Chemical Admixtures (Conplast SP 430) | Properties as per IS 9103 |
|---|---|
| Specific Gravity | 1.20 |
| pH | 6.73 |
| Chloride content | 0.2% |

## IV. MIX DESIGN

Concrete mix design was done as per IS 10262-2009 for M50 grade. The quantities of ingredient materials and mix proportions as per design are as under Table No.10

Table No. 10 Details of concrete mix proportion adopted for using M-Sand

| Cement | F. A | C.A | Water |
|---|---|---|---|
| 450 $kg/m^3$ | 621 $kg/m^3$ | 1235 $kg/m^3$ | 165 $kg/m^3$ |
| 1 | 1.38 | 2.74 | 0.33 |

Specimen Preparation

In order to compare the properties of GGBS Concrete, cubes and beams were casted and compared with using conventional concrete as detailed below:

Table No.11 Details of Specimens

| Types of Concrete | Cube (150x150 x 150mm) | Beam (150x150x700mm) |
|---|---|---|
| Conventional Concrete | 6 | 3 |
| 40% GGBS + 60% OPC | 6 | 3 |
| 45% GGBS + 55% OPC | 6 | 3 |
| 50% GGBS + 50% OPC | 6 | 3 |
| 55% GGBS + 45% OPC | 6 | 3 |
| 60% GGBS + 40% OPC | 6 | 3 |
| 65% GGBS + 35% OPC | 6 | 3 |
| 70% GGBS + 30% OPC | 6 | 3 |

Testing of the Specimens

Compressive strength and Flexural strength of hardened concrete was tested in accordance with IS 516. For each mix, the strength was determined on concrete specimens as shown in Table No. 11 at $7^{th}$ and $28^{th}$ days.

## V. DISCUSSION ON THE TEST RESULTS

a. Slump Cone Test

The workability of GGBS Concrete using M- Sand as given in Table No.12.

Table No.12

| Types of Concrete | Slump Value (mm) |
|---|---|
| Conventional Concrete | 110 |
| 40% GGBS + 60% OPC | 135 |
| 45% GGBS + 55% OPC | 160 |
| 50% GGBS + 50% OPC | 170 |
| 55% GGBS + 45% OPC | 175 |
| 60% GGBS + 40% OPC | 180 |
| 65% GGBS + 35% OPC | 180 |
| 70% GGBS + 30% OPC | 185 |

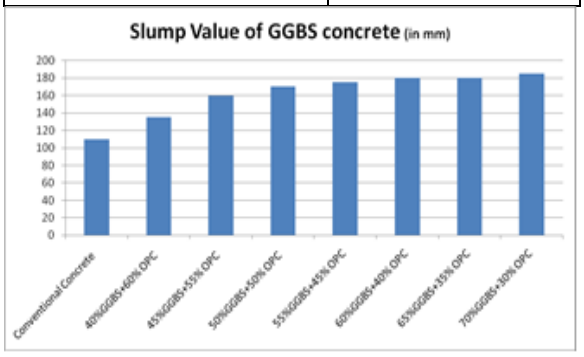


Fig.1. Slump Value of GGBS Concrete

b. Compressive Strength

The mean compressive strength of 150 mm concrete cubes was determined for specimens which were kept for curing for 7 days and 28 days and reported in Table No.13

Table: 13. Compressive strength

| Types of Concrete | Compressive Strength (Mpa) | |
|---|---|---|
| | 7th Day | 28th Day |
| Conventional Concrete | 56.69 | 66.77 |
| 40% GGBS + 60% OPC | 55.81 | 69.40 |
| 45% GGBS + 55% OPC | 53.72 | 71.96 |
| 50% GGBS + 50% OPC | 48.98 | 63.76 |
| 55% GGBS + 45% OPC | 37.28 | 54.78 |
| 60% GGBS + 40% OPC | 33.76 | 46.52 |
| 65% GGBS + 35% OPC | 32.56 | 44.35 |
| 70% GGBS + 30% OPC | 25.82 | 36.82 |

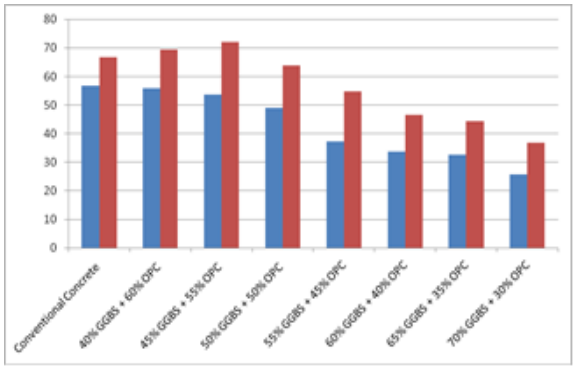



Fig. 2. Compressive strength of GGBS Concrete


FLEXURAL STRENGTH TEST ON BEAMS:

The flexural strength of concrete beam was performed on universal testing machine. The specimens were tested at the age of 7th & 28th days subjected to two points loading and results were reported in Table No. 14


Fig.3 Flexural Strength Test prior to Crack


Fig.4 Flexural Strength Test at Crack

Table No.14 Flexural Strength

| Types of Concrete | Flexural Srength (Mpa) | |
|---|---|---|
| | 7th Day | 28th Day |
| Conventional Concrete | 3.715 | 5.321 |
| 40% GGBS + 60% OPC | 3.850 | 5.320 |
| 45% GGBS + 55% OPC | 3.565 | 5.270 |
| 50% GGBS + 50% OPC | 3.232 | 4.885 |
| 55% GGBS + 45% OPC | 2.856 | 3.763 |
| 60% GGBS + 40% OPC | 2.560 | 3.542 |
| 65% GGBS + 35% OPC | 2.296 | 3.027 |
| 70% GGBS + 30% OPC | 2.002 | 2.764 |

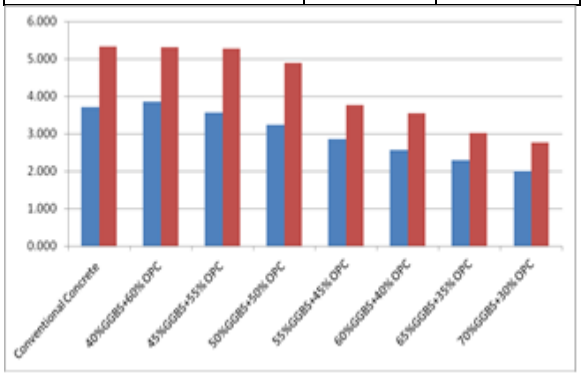



Fig 5. Flexural Strength of GGBS


## VI. RESULTS AND CONCLUSIONS

The concrete was prepared for M50 grade concrete with partial replacement of cement by GGBS with various percentages of 0%, 40%, 45%, 50%, 55%, 60%, 65% & 70% using 100% M-Sand as fine aggregate. The specimens were casted for 7 days, 28 days and then tested. The results are presented below. From the above results, following conclusions were made…

- The workability of concrete using GGBS and M-Sand is increased from 22 % to 68 % and it possesses good pumpable and compaction characteristics.
- It achieved maximum Compressive strength when there is partial replacement of 45% GGBS with 100% M-Sand. But the target mean strength as specified by IRC is satisfied at the partial replacement of 50% GGBS. So the optimum percentage of replacement of GGBS is 50%.
- The maximum flexural strength achieved for the partial replacement of 40% GGBS which is same as conventional concrete. Even at 50% GGBS, the results are almost same without much change.
- Based on this study, 50% GGBS is found optimum which would result in 23% cost saving approximately.

A. Abbreviations and Acronyms

GGBS – Ground Granulated Blast Furnace Slag
OPC – Ordinary Portland Cement
M-Sand – Manufactured Sand
FA – Fine Aggregate
CA – Coarse Aggregate

B. Units

N/mm2 - “Newton per square millimeter (Mpa)
mm - “millimeter”

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