# Investigating the Strength Properties of Cement Mortar Using Ground Granulated Blast Furnace Slag (GGBFS)

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***Abstract-*** **The current construction boom has made it imperative to develop an additional cementing material that improves strength while having less of an adverse transform on the circumstances. Through the precipitation of calcium carbonate, GGBFS has ability to increase the strength of cement mortar. To determine its application in this regard, GGBFS is used in the current study. GGBFS is tested for consistency and specific gravity, among other things, to see how it affects cement. In the current study, inspection including the compression strength, density, and water absorption test are utilized to determine how the mechanical characteristics of cement mortar vary. The compressive test of the mortar cube was seen to rise (at 7 and 28 days) as the content of GGBFS increased up to 30%. During injecting GGBFS, the mean compressive strength surpasses that of the control samples by 65% and 99%, respectively, after 7 and 28 days. After a week of curing, the strength may have increased more because of the sample's increased density and decreased water cement ratio. The minimal cumulative water absorption of 2.93%, measured with a 30% replacement of cement by GGBFS, indicates the hardness of mortar.**

**Keywords–** Ground granulated blast furnace slag, workability, compressive strength, Cement, Sand, Flowability.

## 1. INTRODUCTION

Cement mortar fundamental function in construction and its vital part in ensuring structural integrity the routine use of Portland cement in mortar mixtures, together with the related resource use and environmental issues.

The need of reducing the environmental impact of construction materials and a renewed focus on sustainable construction procedures. The function of supplemental cementitious materials (SCMs), which partly substitute conventional cement, in improving sustainability.

GGBFS: An afterthought in the iron and steel industries. Its pozzolanic qualities and chemical makeup highlight its potential as a viable partial Portland cement substitute. It is vital to investigate and comprehend the characteristics of cement mortar when integrating GGBFS, stressing possible benefits, including enhanced stability, diminished carbon emissions, and economic viability.

Significant findings from several academic investigations on the partial substitution of cement with GGBFS include the following.

1. By lowering CO2 emissions and conserving natural resources, the reprocess of slag as a byproduct helps to lower environmental pollution.
2. Compressive strength generally rises with increasing GGBFS percentage at later ages, although it falls with increment of GGBFS percentage in the majority of cases.
3. When the water/binder ratio falls for a given workability, the GGBFS content increases, resulting in beneficial impacts on realistic.
4. Thermal cracking is less likely to occur with GGBFS concrete because its heat of hydration occurs more slowly.
5. The percentage of GGBFS likewise declines with increasing age, but it increases with increasing age in split tensile and flexural strength.

## 2. LITERATURE REVIEW

The performance and impact of GGBFS on both newly formed and toughened concrete were examined by Wang Ling et al. (2004) [1]. GGBFS-treated concrete resists chemical corrosion and has excellent strength and low heat of hydration.

Shariq et al (2008) [2] looked into how the curing process affected the development of the compressive strength of cement mortar and concrete containing ground granulated blast furnace slag. Using GGBFS replacement of 20%, 40% and 60% for diver's sand kinds, the compressive strength growth of cement mortar is computed. In a similar manner, the strength development of concrete with 20, 40, and 60% substitution of GGBFS is investigated on two concrete classes. According to test results, adding 20% and 40% GGBFS increases mortar's compressive strength after 28 days and 150 days, respectively, and is highly significant.

Islam et al.[3] talked about the outcomes of engage slag in different amounts (10% – 70%) to replace some of the cement. Through testing several aspects of concrete properties, he found that the compressive and tensile strengths of mortar mixes containing slag decrease at early curing ages (3 and 7 days). At ages 3, 7, 14, 28, 60, 90, and 180 days, these values were measured. With rising curing age, however, the rate of reduction decreases less quickly. Slag has 19% compressive strength and 25% tensile strength compared to OPC mortar, hence the best usage of it in mortar is as a 40% replacement of cement. According to his findings, using slag reduces the likelihood of thermal cracking by reducing the amount of cement in a mortar mix and the heat of hydration. [4, 5, 6]

## 3. RESULTS:

### 3.1 GGBFS

GGBFS is produced by blast-firing molten iron slag, a byproduct of making iron and steel, in steam or water. A glassy, granular product is produced by this method, which is then dried and processed into a fine particle. After mixing with water, GGBFS acts as a latent hydraulic binder to create calcium silicate hydrates (C-S-H). It is a chemical that increases strength and prolongs the life of concrete. [7, 8, 9, 10]

**Figure – 1 GGBFS**

#### *3.1.1 Fineness*

GGBFS fineness is a gauge of the slag particles size distribution. Because fineness affects the slag reactivity when utilized as an additional cementitious material in concrete, fineness is a crucial feature. This measurement displays the aggregate surface area of the particles inside a unit mass of GGBFS.

**Table – 1 Fineness of GGBFS**

| S No. | Weight [sample (gm)] W1 | Weight (90-micron sieve) W2 | Fineness |
|---|---|---|---|
| **1** | 100 | 2.5 | 2.5% |
| **2** | 100 | 1.9 | 1.9% |
| **3** | 100 | 1.5 | 1.5% |
| | | **Average** | **1.9 %** |

#### *3.1.2 SPECIFIC GRAVITY*

The ratio of GGBFS's density to that of water is known as its specific gravity. GGBFS, this essential property helps to comprehend the relationship between the material's mass and volume. By weighing a certain volume of GGBFS in relation to their volume of water, one can normally calculate its SG.

**Table – 2 Specific gravities of GGBFS**

| S No. | Specific gravity |
|---|---|
| **Sample 1** | 2.69 |
| **Sample 2** | 2.78 |
| **Sample 3** | 2.82 |
| **Average** | **2.76** |

### 3.2 CEMENT

This scientific experiment aims to determine the setting time of several types of cement. Vicat device is used. In order to verify its standard consistency, cement paste is created.

#### *3.2.1 CONSISTENCY TEST*

Amount of water required to make a paste

**Table – 3 Consistency test**

| S No. | Water Added (gm) | Penetration (mm) |
|---|---|---|
| **1** | 84 | 25 |
| **2** | 90 | 10 |
| **3** | 99 | 7 |

RESULT: - Consistency = 33%

#### *3.2.2 SOUNDNESS TEST*

There are two methods for determining the soundness of cement: the autoclave and the Le-Chatelier method. Soundness is the stability to change in volume during process of setting and hardening.

**Table – 4 Soundness test**

| S No. | Expansion (mm) |
|---|---|
| Sample 1 | 2 |
| Sample 2 | 4 |
| Sample 3 | 6 |
| Average | 4 |

#### *3.2.3 FINENESS*

Cement fineness can be measured in two methods: (a) By sieving. (b) By measuring the specific surface—the total area of all the particles in a single gram of cement using an air-permeability device. measured in either $m^2/kg$. Typically, the Blaine Air Permeabilities Device is utilized.

**Table – 5 Fineness of cement**

| S No. | Weight of GGBFS sample (gm) $W_1$ | Weight retained on 90micron sieve $W_2$ | Fineness of GGBFS |
|---|---|---|---|
| **1** | 100 | 3.5 | 3.5% |
| **2** | 100 | 4 | 4% |

| | | | |
|---|---|---|---|
| 3 | 100 | 4.5 | 4.5% |
| | | **Average** | **4%** |

## 3.3 SAND

Sand is subjected to tests to determine this appropriateness for various uses, especially in construction sector. Physical, chemical, and performance testing are the three main categories into which sand test types can be divided [11, 12].

### *3.3.1 BULKING OF SAND:*

Bulking of sand, or fine aggregate, is the phenomena wherein an increase in moisture content causes an increase in sand volume. Grains of Sand are surrounded by thin layers due to the moisture content of the sand. Each particle applies pressure as a result. As a result, they separate from one another, increasing the volume [13, 14].

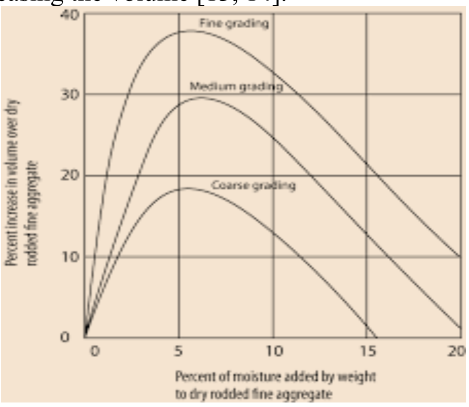


**Figure – 2** Bulking of sand

**Table – 6** Bulking of sand

| S No. | Water content (%) | Bulking of sand (%) |
|---|---|---|
| **1** | **0** | **0** |
| **2** | **1** | **18.18** |
| **3** | **2** | **20** |
| **4** | **3** | **22.72** |
| **5** | **4** | **25.45** |
| **6** | **5** | **27.27** |
| **7** | **6** | **15.45** |

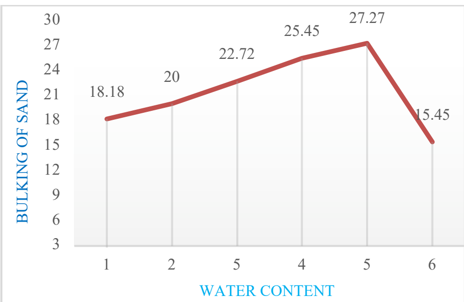


**Figure – 3** Bulking of sand

## 3.4 MORTAR

A malleable paste called mortar hardens to connect building materials like stones, bricks and concrete masonry units. It also fills and seals irregular spaces between the materials, evenly distributes their weight, and can occasionally be used to add beautiful colors or patterns to masonry walls.

### *3.4.1 FLOW-ABILITY TEST ON MORTAR:*

The horizontal spread that a cement mortar undergoes as a result of many dynamic impacts is measured by the flow test. Spread causes the mortar pile's height to drop (wet mixtures preserve volume).

**Table – 7** Flow-Ability test on mortar

| S No. | Replacement by (GGBFS) (%) | Water content ratio |
|---|---|---|
| **1** | 0 | 0.59 |
| **2** | 10 | 0.57 |
| **3** | 20 | 0.55 |
| **4** | 30 | 0.53 |

### *3.4.2 DENSITY OF MORTAR:*

A density test is performed to find out the hardness or denseness of a mortar.

**Table – 8 Density of mortar**

| S No. | Replacement (%) | Density (gm/ml) |
|---|---|---|
| **1** | 0 | 1.10 |
| **2** | 10 | 1.13 |
| **3** | 20 | 1.16 |
| **4** | 30 | 1.18 |

### *3.4.3 WATER ABSORPTION OF MORTAR:*

Water absorption is one of the key characteristics that affects how long mortars last. It is typically assessed by drying a specimen to a constant mass, submerging it in water, and calculating the mass gain as a percentage of the dry mass. Absorption by good mortar mixtures is well below ten percent of quanity.

**Table – 9 Water absorption of mortar**

| S No. | Replacement by GGBFS | Water absorption |
|---|---|---|
| **1** | 0% | 8.35 |
| **2** | 10% | 6.35 |
| **3** | 20% | 4.84 |
| **4** | 30% | 2.92 |

### *3.4.4 COMPRESSIVE STRENGTH TEST OF MORTAR:*

One popular method for determining the strength of mortar is the compressive strength test. The following equipment is required to complete this test:

- Cube moulds: These are used in the process of preparing mortar samples. The moulds should be 70.6 mm x 70.6 mm x 70.6 mm in dimension and constructed of steel or cast iron.
- Mixing apparatus: To guarantee uniform mixing of mortar, such as a mechanical mixer or a mixing paddle coupled to a drill, should be employed.
- Testing apparatus: To test the specimens, a compression testing apparatus with a minimum 500 kN capacity should be utilized.

**Table – 10 Compressive strength at 7 day**

| S No. | GGBFS (%) | Load (kN) | Compressive strength (MPa) |
|---|---|---|---|
| **1** | 0 | 20.30 | 7.38 |
| **2** | 10 | 22.23 | 9.58 |
| **3** | 20 | 28.66 | 11.81 |
| **4** | 30 | 41.26 | 14.37 |

**Table – 11 Compressive strength at 28 day**

| S No. | GGBFS (%) | Load (kN) | Compressive strength (MPa) |
|---|---|---|---|
| **1** | 0 | 31.80 | 11.36 |
| **2** | 10 | 34.07 | 16.21 |
| **3** | 20 | 47.58 | 18.51 |
| **4** | 30 | 72.35 | 26.18 |

## 4. CONCLUSIONS

The objective of this work experience with GGBS-based concrete is to enhance mortar density. The use of GGBFS in place of concrete increases compressive strength while reducing the substance of the concrete, which lowers CO2 emissions. Adding GGBFS to cement mortar as a partial replacement is highly beneficial since it lowers the water cement ratio, which increases the mortar's strength.

By adding GGBFS to the cement mortar in place of some of the cement, we can also enhance the density of the mortar and ultimately give it more compressive strength [15, 16]. The strength of mortar is increased because the inclusion of GGBFS causes the density of the mortar to increase while the absorption of water decreases, indicating greater resistance to moisture. Cost-wise, GGBFS's market expenses, such as those associated with bundling and transferring, are frequently not precisely OPC. In this approach, the partial replacement of OPC in cement by GGBFS is not only feasible but also promotes the environmentally benign conversion of waste slag into a profitable product made from large-scale iron and steel production. Adding GGBFS to the mortar can strengthen it by partially substituting cement, based on our testing results.

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