# COMPARITIVE STUDY OF DIFFERENT TYPES OF SLAGS IN CONCRETE

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**Abstract** - *Concrete is the most-used man-made product in the world. Concrete is widely used for making many types of structural components for different civil engineering applications. Due to limitation of quality natural resources for making concrete, the waste utilization in production of concrete are major concern in advances of civil engineering. The enormous quantity of Blast Furnace Slag (BFS), Iron Slag, Copper Slag is generally dumped in unscientific manner create environmental issues and little is used for landfill purpose without any technical input. Along with BFS iron slag and copper slag are available in enormous amount. It is interesting to know whether Blast Furnace Slag (BFS), Iron Slag, Copper Slag can be utilized as a fine aggregates (i.e. as a sand) to produce concrete.*

***Keywords*** **-** Slag, Copper Slag, Iron Slag, Blast Furnace Slag, strength, cement, concrete (M20), design mix

## 1 – INTRODUCTION

Concrete is a composite material composed of water, coarse granular material (the fine and coarse aggregate or filler) embedded in a hard matrix of material (the cement or binder) that fills the space among the aggregate particles and glues them together. Concrete is widely used for making architectural structures, foundations, brick or block walls, pavements, bridges or overpasses, highways, runways, parking structures, dams, pools/reservoirs, pipes, footings for gates, fences and poles and even boats. Concrete is used in large quantities almost everywhere mankind has a need for infrastructure

The amount of concrete used worldwide, ton for ton, is twice that of steel, wood, plastics, and aluminium combined. Concrete's use in the modern world is exceeded only by that of naturally occurring water. Concrete is also the basis of a large commercial industry.

Due to global warming the need to cut down energy consumption has increased. The effect of global warming has impacted everyone on the planet and is a well-recognised concept.

The interest of construction community in using waste or recycled materials in concrete is increasing because of the emphasis placed on sustainable construction.

As slag is an industrial by- product, its productive use grant an chance to relocate the utilization of limited natural resources on a large scale. Iron slag is a byproduct obtained in the manufacture of pig iron in the blast furnace and is produced by the blend of down to earth constituents of iron ore with limestone flux. Iron and steel slag can be differentiating by the cooling processing when removed from the furnace in the industry. Mostly, the slag consists of magnesium, aluminium silicates calcium and manganese in various arrangements. Even though the chemical composition of slag same but the physical properties of the slag vary with the varying.

Copper slag is used in the concrete as one of the alternative materials. It is the waste product of copper. The safe disposal of this waste is a lack, costly and causes environmental pollution. The construction industry is the only area where the safe use of waste material (copper slag) is possible. When it is introduced in concrete as a replacement material, it reduces the environmental pollution, space problem and also reduces the cost of concrete.

The main objective of this investigation is to evaluate the effect of different types of slags on the compressive strength and the other properties of concrete and to evaluate the possibility of using slag in concrete without sacrificing the strength. The following were also considered.

1. Partial substitute for the fine aggregate.
2. To determine the percentage of slag which gives maximum strength when compared to control concrete

## 2 – MATERIAL AND DESIGN METHODOLGY

### 2.1. Materials

The properties of material used for making concrete mix are determined in laboratory as per relevant codes of practice. Different materials used in present study were cement, coarse aggregates, and fine aggregates, in addition to plastic bags and iron slag.

**Ordinary Portland Cement -** Ordinary Portland cement of grade 43 was used in concrete. OP cement does not contain any pozzolanic material. Consistency of Cement was found to be 29% and it was well sound with a tensile strength of 3.8 N/mm$^2$ after 7 days and compressive strength of 48 N/mm$^2$ after 28 days.

**Aggregates –**

- Fine aggregate: fine aggregate was used locally available. It was sieved through 2.36mm IS sieve. Fineness modulus was 2.59, and of zone - II
- Coarse aggregate: broken granite rocks of size 10mm and 20mm which were used, of abrasion value of 30%, crushing value of 24.3%

**Copper slag -** Copper slag is a by-product of copper extraction by smelting. The Copper Slag was properly sieved and fineness modulus of slag is 3.29 (Zone 2)

**Blast Furnace Slag -** Ground-granulated blast-furnace slag (GGBS or GGBFS) is obtained by quenching molten iron slag. The Slag was properly sieved and fineness modulus of slag is 2.655 (Zone 2)

**Iron Slag -** The iron and steel slag that is generated as a by-product of iron and steel manufacturing processes. The Slag was properly sieved and fineness modulus of slag is 3.3145 (Zone 2)

**Water -** The potable water from the college was used for mixing and curing the concrete.

## 2.2. Methodology

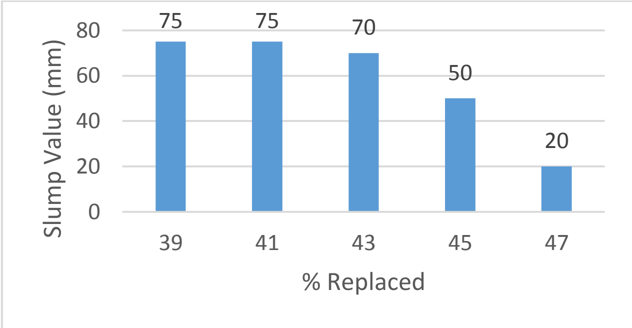
In this study we follow the under mentioned model for the design, planning, implementation and achievement of the project:
1. The materials to be used will be collected.
2. Various tests on the materials will be done to check quality standards.
3. Mix design of the concrete will be done (M20).
4. Slag is added at different percentages with respect to weight of aggregate as a replacement of aggregate.
• Blast furnace slag in concrete (21, 23, 25, 27, 29 %)
• Copper Slag in concrete (39, 41, 43, 45, 47 %)
• Iron Slag in concrete (24, 26, 28, 30, 32 %)
5. Nine cubes will be casted for every percentage of replacement. The dimension of test cube is 0.15m x 0.15m x 0.15m. According to the volume of material required for 9 cubes, materials are gathered and are mixed to prepare the concrete.
6. The prepared concrete will then be casted in the form of test cubes. The cube while being filled is tamped by tamping rod to reduce the number of voids in concrete.
7. The cube will be left for 24 hours to gain shape.
8. After 24 hours, the cubes then will be taken off from the moulds.
9. They will be left for curing then.
10. Then their compressive strength will be checked from 3, 7 and 28 days from casting.
11. Analysis of results will be done then.

## 3 - TEST RESULTS AND ANALYSIS

### 3.1. SLUMP TEST OF CONCRETE

**Table 1**: Slump Test with partial replacement of fine aggregate with copper slag

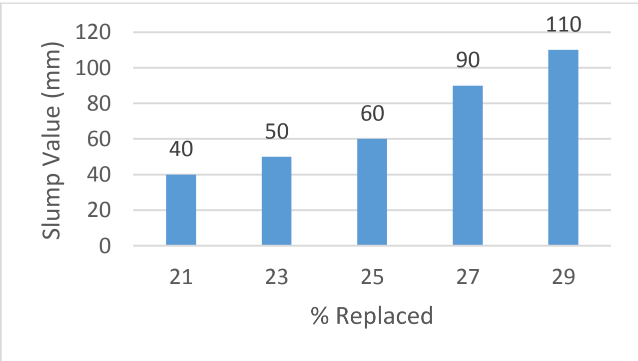
| S.NO. | % Replaced | Slump Value (mm) |
|---|---|---|
| 1. | 39 | 75 |
| 2. | 41 | 75 |
| 3. | 43 | 70 |
| 4. | 45 | 50 |
| 5. | 47 | 20 |




**Graph 1:** Slump for Copper slag

**Table 2:** Slump Test with partial replacement of fine aggregate with Blast Furnace Slag

| S.NO. | % Replaced | Slump Value (mm) |
|---|---|---|
| 1. | 21 | 40 |
| 2. | 23 | 50 |
| 3. | 25 | 60 |
| 4. | 27 | 90 |
| 5. | 29 | 110 |

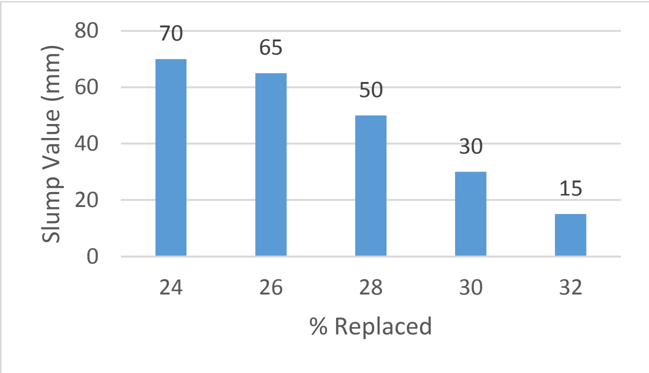



**Graph 2:** Slump for blast furnace slag

**Table 3:** Slump Test with partial replacement of fine aggregate with Iron slag

| S.NO. | % Replaced | Slump Value (mm) |
|---|---|---|
| 1. | 24 | 70 |
| 2. | 26 | 65 |

| | | |
|---|---|---|
| 3. | 28 | 50 |
| 4. | 30 | 30 |
| 5. | 32 | 15 |



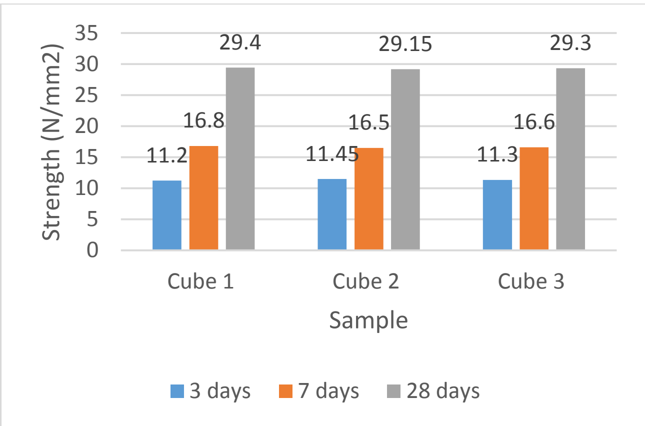

**Graph 3:** Slump for iron slag

### 3.2. COMPRESSIVE STRENGTH TESTING OF CONCRETE CUBES (.15X.15X.15 M) WITH REPLACEMENT OF FINE AGGREGATE WITH COPPER SLAG.

#### 3.2.1. For 39% replacement

**Table 4:** Compressive strength for 39% replacement

| S.No. | No. of Days | Cube 1 | Cube 2 | Cube 3 |
|---|---|---|---|---|
| 1. | 3 days | 11.20 | 11.45 | 11.30 |
| 2. | 7 days | 16.80 | 16.50 | 16.60 |
| 3. | 28 days | 29.40 | 29.15 | 29.30 |

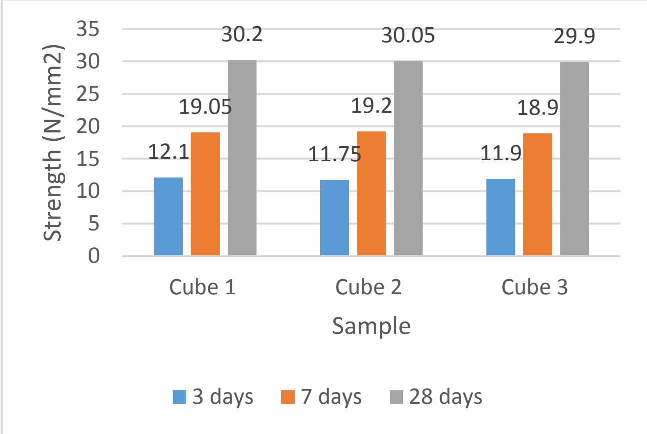



**Graph 4:** 39% replacement

#### 3.2.2. For 41% replacement

**Table 5:** Compressive strength for 41% replacement

| S.No. | No. of Days | Cube 1 | Cube 2 | Cube 3 |
|---|---|---|---|---|
| 1. | 3 days | 12.10 | 11.75 | 11.90 |
| 2. | 7 days | 19.05 | 19.20 | 18.90 |
| 3. | 28 days | 30.20 | 30.05 | 29.90 |

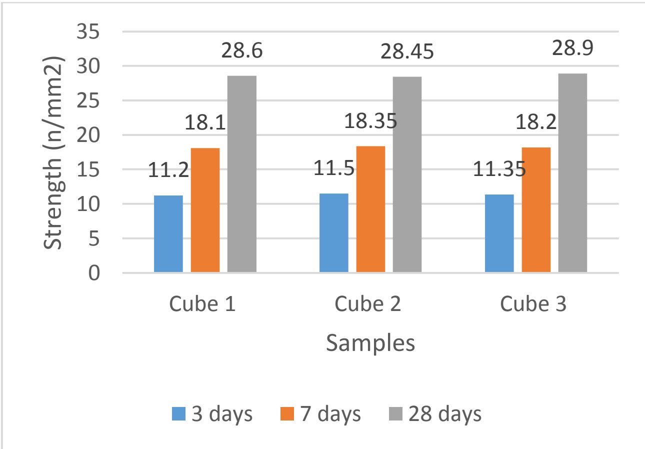



**Graph 5:** 41% replacement

#### 3.2.3. For 43% replacement

**Table 6:** Compressive strength for 43% replacement

| S.No. | No. of Days | Cube 1 | Cube 2 | Cube 3 |
|---|---|---|---|---|
| 1. | 3 days | 11.20 | 11.50 | 11.35 |
| 2. | 7 days | 18.10 | 18.35 | 18.20 |
| 3. | 28 days | 28.60 | 28.45 | 28.90 |

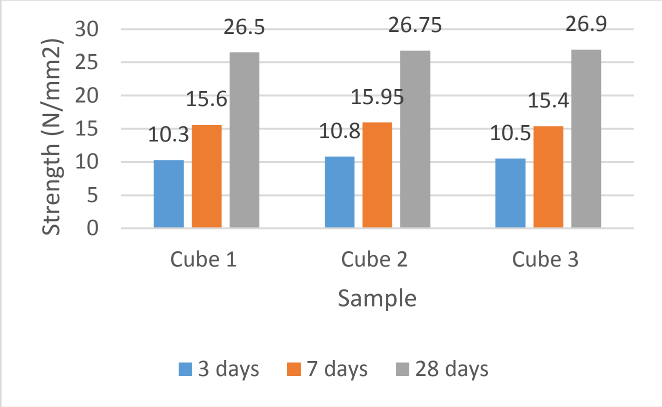



**Graph 6:** 43% replacement

#### 3.2.4. For 45% replacement

**Table 7:** Compressive strength for 45% replacement

| S.No. | No. of Days | Cube 1 | Cube 2 | Cube 3 |
|---|---|---|---|---|
| 1. | 3 days | 10.30 | 10.80 | 10.50 |
| 2. | 7 days | 15.60 | 15.95 | 15.40 |
| 3. | 28 days | 26.50 | 26.75 | 26.90 |

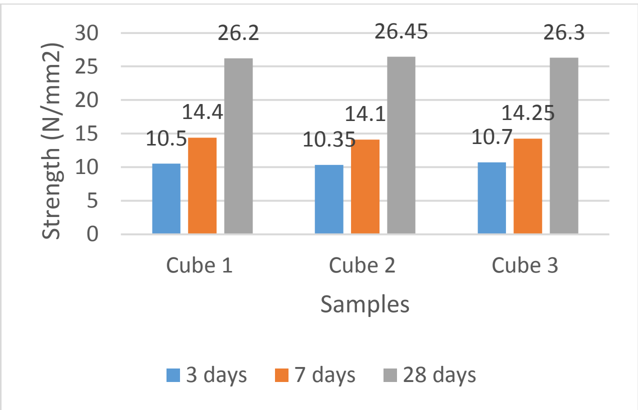



**Graph 7:** 45% replacement

### 3.2.5. For 47% replacement

**Table 8:** Compressive strength for 47% replacement

| S.No. | No. of Days | Cube 1 | Cube 2 | Cube 3 |
|---|---|---|---|---|
| 1. | 3 days | 10.50 | 10.35 | 10.70 |
| 2. | 7 days | 14.40 | 14.10 | 14.25 |
| 3. | 28 days | 26.20 | 26.45 | 26.30 |



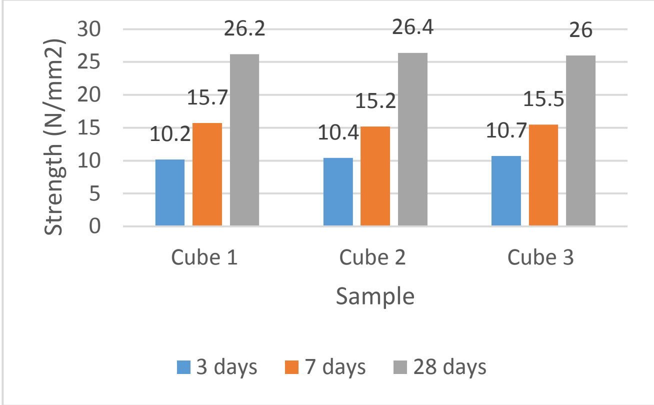

**Graph 8:** 47% replacement

## 3.3. COMPRESSIVE STRENGTH TESTING OF CONCRETE CUBES (.15X.15X.15 M) WITH REPLACEMENT OF FINE AGGREGATE WITH BLAST FURANCE SLAG

### 3.3.1. For 21% replacement

**Table 9**: Compressive strength for 21% replacement

| S.No. | No. of Days | Cube 1 | Cube 2 | Cube 3 |
|---|---|---|---|---|
| 1. | 3 days | 10.20 | 10.40 | 10.70 |
| 2. | 7 days | 15.70 | 15.20 | 15.50 |
| 3. | 28 days | 26.20 | 26.40 | 26.00 |

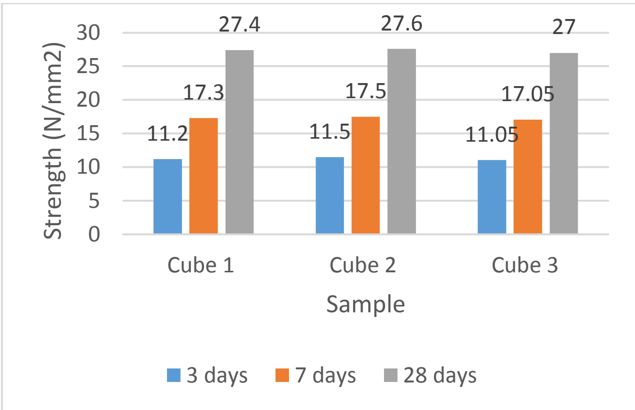



**Graph 9:** 21% replacement

### 3.3.2. For 23% replacement

**Table 10:** Compressive strength for 23% replacement

| S.No. | No. of Days | Cube 1 | Cube 2 | Cube 3 |
|---|---|---|---|---|
| 1. | 3 days | 11.20 | 11.50 | 11.05 |
| 2. | 7 days | 17.30 | 17.50 | 17.05 |
| 3. | 28 days | 27.40 | 27.60 | 27.00 |

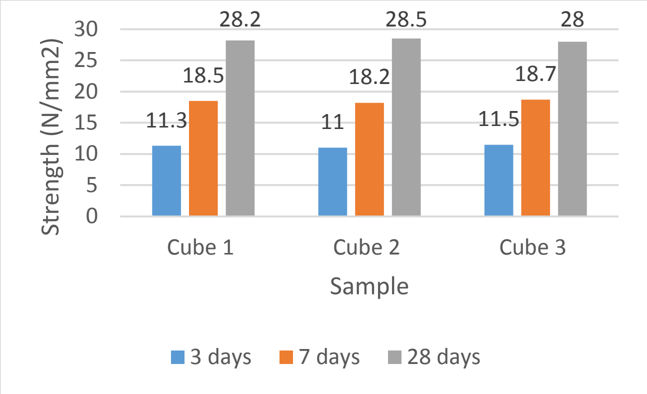



**Graph 10:** 23% replacement

### 3.3.3. For 25% replacement

**Table 11:** Compressive strength for 25% replacement

| S.No. | No. of Days | Cube 1 | Cube 2 | Cube 3 |
|---|---|---|---|---|
| 1. | 3 days | 11.30 | 11.00 | 11.50 |
| 2. | 7 days | 18.50 | 18.20 | 18.70 |
| 3. | 28 days | 28.20 | 28.50 | 28.00 |

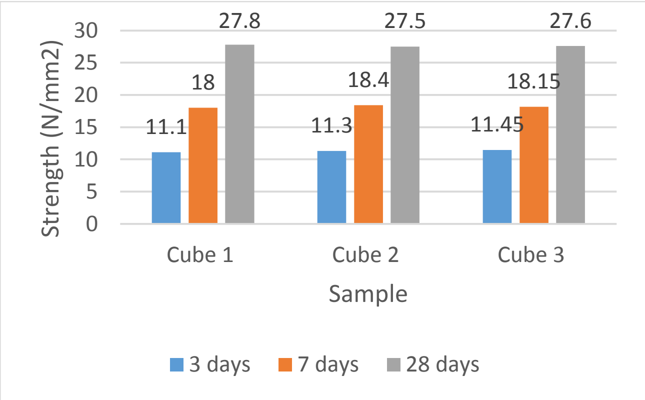



**Graph 11:** 25% replacement

### 3.3.4. For 27% replacement

**Table 12:** Compressive strength for 27% replacement

| S.No. | No. of Days | Cube 1 | Cube 2 | Cube 3 |
|---|---|---|---|---|
| 1. | 3 days | 11.10 | 11.30 | 11.45 |
| 2. | 7 days | 18.00 | 18.40 | 18.15 |
| 3. | 28 days | 27.80 | 27.50 | 27.60 |

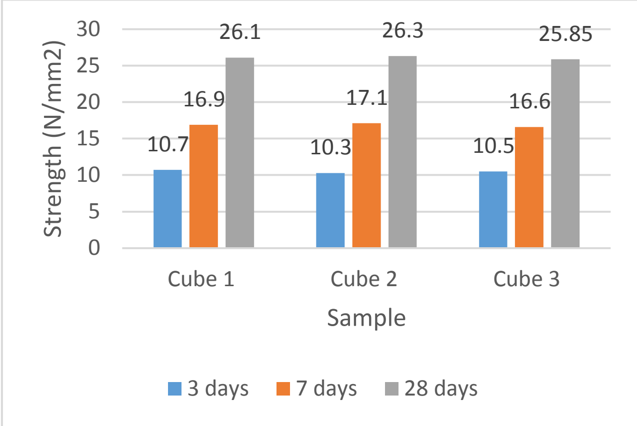



**Graph 12:** 27% replacement

### 3.3.5. For 29% replacement

**Table 13:** Compressive strength for 29% replacement

| S.No. | No. of Days | Cube 1 | Cube 2 | Cube 3 |
|---|---|---|---|---|
| 1. | 3 days | 10.70 | 10.30 | 10.50 |
| 2. | 7 days | 16.90 | 17.10 | 16.60 |
| 3. | 28 days | 26.10 | 26.30 | 25.85 |



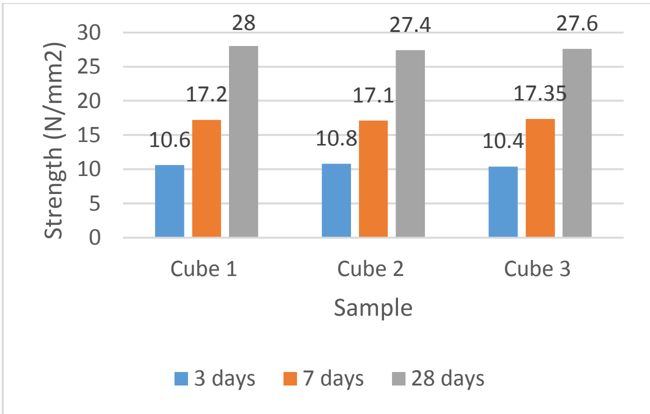

**Graph 13:** 29% replacement

### 3.4. COMPRESSIVE STRENGTH TESTING OF CONCRETE CUBES (.15X.15X.15 M) WITH REPLACEMENT OF FINE AGGREGATE WITH IRON SLAG

### 3.4.1. For 24% replacement

Table 14: Compressive strength for 24% replacement

| S.No. | No. of Days | Cube 1 | Cube 2 | Cube 3 |
|---|---|---|---|---|
| 1. | 3 days | 10.6 | 10.80 | 10.40 |
| 2. | 7 days | 17.20 | 17.10 | 17.35 |
| 3. | 28 days | 28.00 | 27.40 | 27.60 |

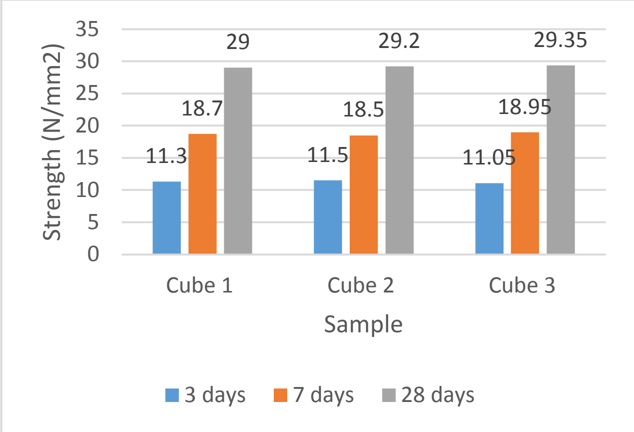



**Graph 14:** 24% replacement

### 3.4.2. For 26% replacement

**Table 15:** Compressive strength for 26% replacement

| S.No. | No. of Days | Cube 1 | Cube 2 | Cube 3 |
|---|---|---|---|---|
| 1. | 3 days | 11.30 | 11.50 | 11.05 |
| 2. | 7 days | 18.70 | 18.50 | 18.95 |
| 3. | 28 days | 29.00 | 29.20 | 29.35 |

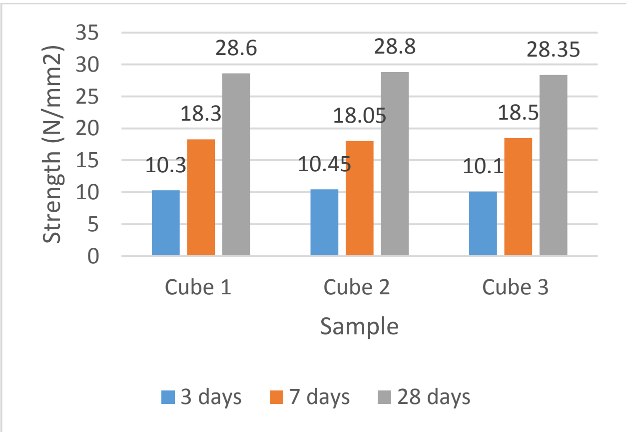



**Graph 15:** 26% replacement

### 3.4.3. For 28% replacement

**Table 16:** Compressive strength for 28% replacement

| S.No. | No. of Days | Cube 1 | Cube 2 | Cube 3 |
|---|---|---|---|---|
| 1. | 3 days | 10.30 | 10.45 | 10.10 |
| 2. | 7 days | 18.30 | 18.05 | 18.50 |
| 3. | 28 days | 28.60 | 28.80 | 28.35 |

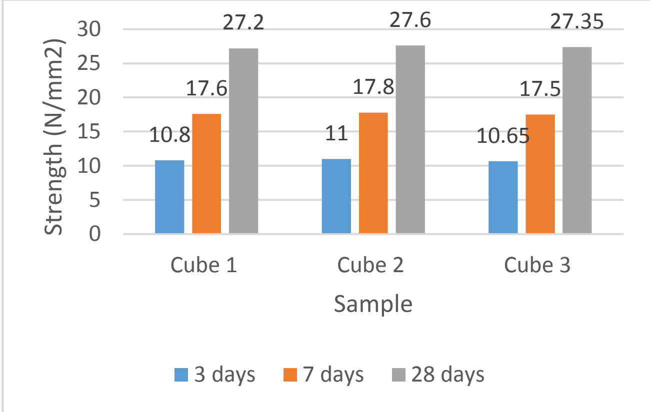



**Graph 16:** 28% replacement

### 3.4.4. For 30% replacement

**Table 24:** Compressive strength for 30% replacement

| S.No. | No. of Days | Cube 1 | Cube 2 | Cube 3 |
|---|---|---|---|---|
| 1. | 3 days | 10.80 | 11.00 | 10.65 |
| 2. | 7 days | 17.60 | 17.80 | 17.50 |
| 3. | 28 days | 27.20 | 27.60 | 27.35 |

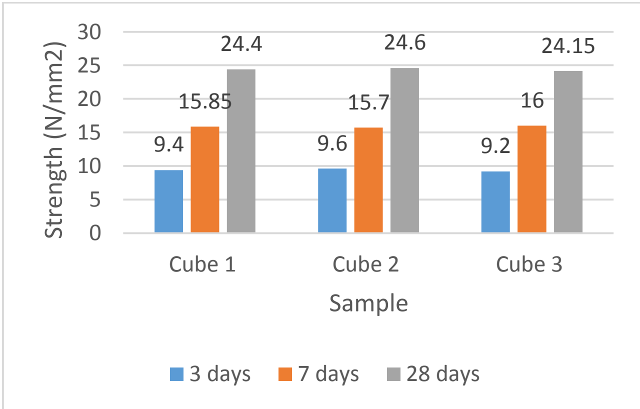



**Graph 17:** 30% replacement

### 3.4.5. For 32% replacement

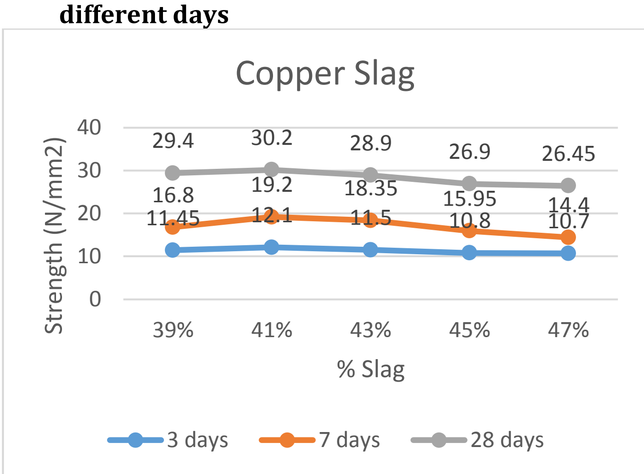
**Table 18:** Compressive strength for 32% replacement

| S.No. | No. of Days | Cube 1 | Cube 2 | Cube 3 |
|---|---|---|---|---|
| 1. | 3 days | 9.40 | 9.60 | 9.20 |
| 2. | 7 days | 15.85 | 15.70 | 16.00 |
| 3. | 28 days | 24.40 | 24.60 | 24.15 |

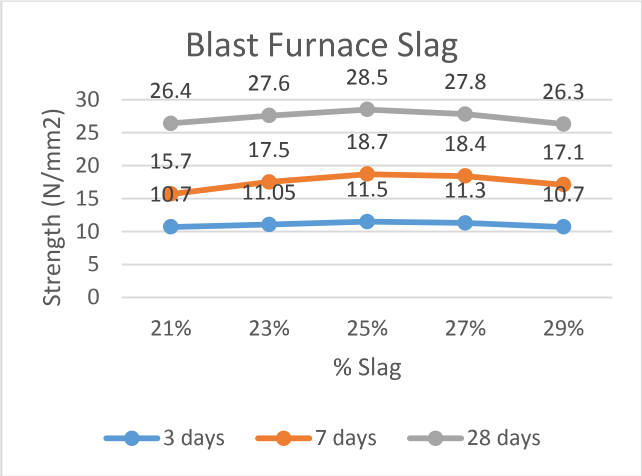



**Graph 18:** 32% replacement

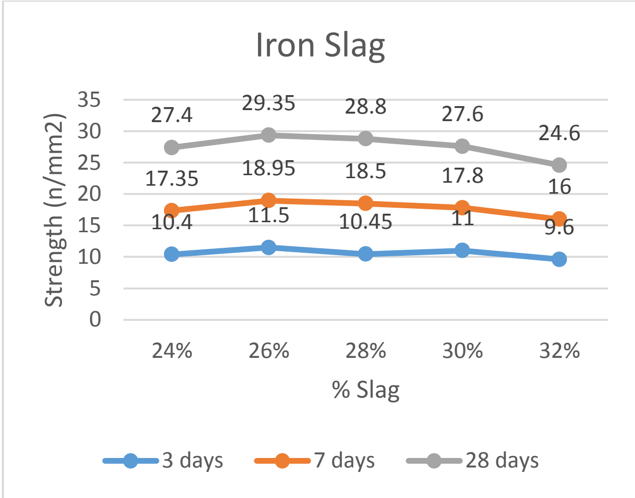
### 3.5. Comparison of strength with different slags at different days



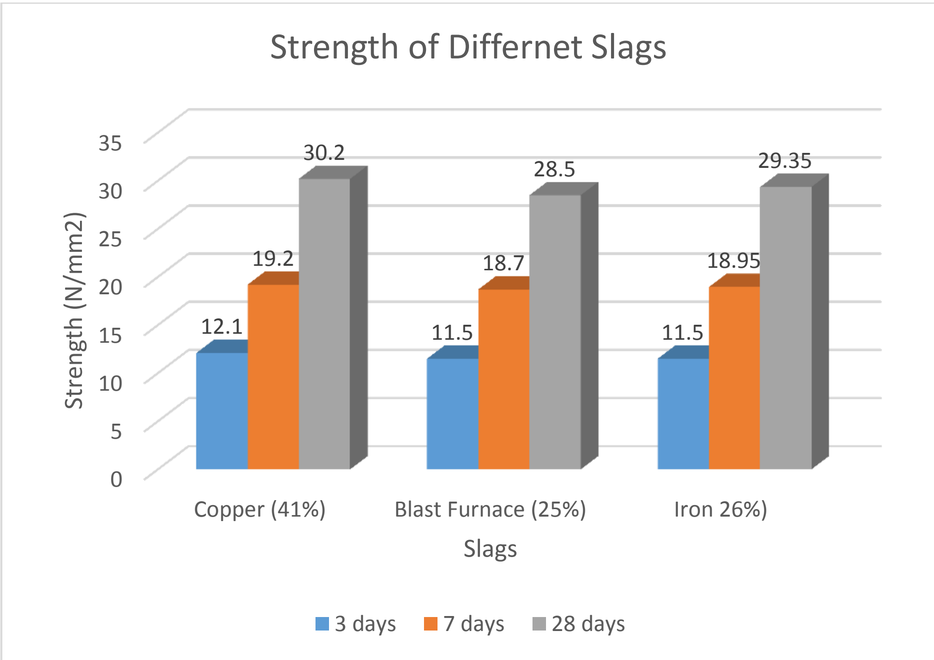

**Graph 19:** strength comparison using different percentage of copper slag




**Graph 20:** strength comparison using different percentage of blast furnace slag




**Graph 21:** strength comparison using different percentage of iron slag




**Graph 19:** strength comparison of different slags

## 4 - CONCLUSIONS

1. The replacement of fine aggregate using slag in concrete increases the density of concrete thereby increases the selfweight of the concrete.
2. The workability of concrete increased with the increase in slag content of fine aggregate replacements at same water-cement ratio upto a certain percentage.
3. After adding 26% iron slag in the mix, there is an increase in compressive strength after 3 days, 7 days and 28 days respectively as compare to control mix. After 28% there is decrease in compressive strength.
4. After adding 41% copper slag in the mix, there is an increase in compressive strength after 3 days, 7 days and 28 days respectively as compare to control mix. After 43% there is decrease in compressive strength.
5. After adding 25% Blast Furnace slag in the mix, there is an increase in compressive strength after 3 days, 7 days and 28 days respectively as compare to control mix. After 27% there is decrease in compressive strength.

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