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# The Behaviour of Concrete by Partial Replacement of Fine Aggregate with Copper Slag and Cement with GGBS - An Experimental Study

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***Abstract :*** *The replacement of natural resources in the manufacture of cement and sand is the present issue in the present construction scenario. Copper slag and Ground Granulated Blast furnace Slag (GGBS) are industrial by-product materials produced from the process of manufacturing copper and iron. Use of Copper slag and GGBS does not only reduce the cost of construction but also helps to reduce the impact on environment by consuming the material generally considered as waste product. Hence in the current study an attempt has been made to minimize the cost of cement and sand with concrete mix grade M25 by studying the mechanical behavior of this concrete mix by partial replacing with advanced mineral admixtures such as Copper slag and GGBS in concrete mix. In this study, partial replacement of Cement with GGBS and Sand with Copper Slag considered. Experimental study is conducted to evaluate the workability and strength characteristics of hardened concrete, properties of concrete have been assessed by partially replacing cement with GGBS, and sand with Copper Slag. The cement has been replaced by GGBS accordingly in the range of 0% (without GGBS), 5%, 10%, 15%, and 20% by weight of cement for M25 mix. The sand has been replaced by Copper slag accordingly in the range of 0% (without Copper slag), 10%, 20%, 30%, and 40% by weight of cement for M25 mix. Concrete mixtures were produced, tested and compared in terms of compressive, flexural and split tensile strength with the conventional concrete.*

***Keywords -*** *Copper slag, GGBS, Workability, Compressive strength, Split tensile strength, Flexural strength.*

## I. Introduction

In the present scenario, as a result of continuous growth in population, rapid industrialization and the accompanying technologies involving waste disposal, the rate of discharge of pollutants into the atmosphere, copper slag and GGBS are few of the industrial by-products which comes out from blast furnace during metal extraction process. In many countries, there is a scarcity of natural aggregate that is suitable for construction, whereas in other countries the consumption of aggregate has increased in recent years, due to increases in the construction Industry. In order to reduce depletion of natural aggregate due to construction, artificially manufactured aggregate and some industrial waste materials can be used as alternatives. As a result for the search of alternatives, copper slag and GGBS are considered best options available. Copper slag which is an industrial by-product of Sterlite Industries Ltd (SIL), Kolkata, India and GGBS which as a by-product of Duracem GGBS company, Auto Nagar, Visakhapatnam. One of the main objective of this thesis is to determine the concrete strength of M25 Grade by partial replacement of sand from 0% to 40% and cement from 0% to 20% with copper slag and GGBS. The other objective is to reduce the cost of construction but also helps to reduce the impact on environment by consuming the material generally considered as waste product.

R R Chavan et.al [1] investigated on the effect of using copper slag as a replacement of fine aggregate on the strength properties. In this study, M25 grade concrete was used and tests were conducted for various proportions of copper slag replacement with sand of 0 to 100% in concrete. It concluded that the maximum compressive strength of concrete increased by 55% at 40% replacement of fine aggregate by copper slag and flexural strength of concrete at 28 days is increased by 14%. Arivalagan [2] investigated to explore the possibility of using copper slag as a replacement of sand in concrete mixtures in various percentages ranging from 0%, 20%, 40% 60%, 80% and 100%. It was observed that, the flexural strength of concrete at 28 days is higher than design mix (without replacement) for 40% replacement of fine aggregate by Copper slag. Atul et al [3] observed that 7 days, 14 days and 28 days compressive strength on 30% replacement of cement reduces about 30% that is from 21.03 N/mm$^2$ to 15.40N/mm$^2$, 23.70 N/mm$^2$ to 16.74 N/mm$^2$ and 26.9 N/mm$^2$ to 18.81 N/mm$^2$ respectively and finally concluded that as the % of BFSP increase, the strength tends to decrease. Brinda. D et al [4] investigated on various corrosion and durability tests on concrete containing copper slag as partial replacement of sand and cement. In this paper, M20 grade concrete was used and the tests were conducted for various proportions of copper slag replacement with sand of 0% to 60%, cement 0% to 20% and combination. The results of compressive, split tensile strength test have indicated that the strength of concrete

increases with respect to the percentage of slag added by weight of fine aggregate up to 40% of additions of 15% of cement. Water permeability in concrete reduced up to 40% replacement of copper slag with that of sand. Venu Malagavelli et al [5] investigation on characteristics of M30 concrete with partial replacement of cement with GGBS and sand with the ROBO sand. The cubes and cylinders are tested for both compressive and tensile strengths. He finally concluded 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.

**1.1 Objectives of the study**

The work reported in this study, Copper slag & GGBS are used as a sand & cement as partial replacement of material in concrete mix. Optimal dosage range of this Copper slag & GGBs are chosen based on concrete mix studies .The ultimate focus of this work is to ascertain the performance of concrete mix containing Copper slag & GGBS and compare it with the controlled concrete mix. This is expected to provide:-

- To partially replace sand with Copper slag and cement GGBS in concrete as it directly influences economy in construction.
- To design and proportion the concrete mix for M25 grade concrete, As per the recommendation of IS:10262:2009.
- To find the Volume proportions of the concrete mixes by partially replacing Sand with Copper slag and cement GGBS in one phase.
- To check the variation of Compressive Strength, Split Tensile Strength and Flexural Strength results by partial replacing the sand 0% to 40% with Copper Slag and the cement 0% to 20% with GGBS compared with controlled concrete and plotting the corresponding graphs separately in another phase.
- Environmental friendly disposal of waste copper and steel slag.

## II. Experimental Programme

**2.1 Materials Used**

**2.1.1 Cement:** Ordinary Portland cement of grade 53 is used for this experimental work.

**2.1.2 Fine aggregate:** The material which passes through BIS test sieve number 4 (4.75mm) is termed as fine aggregate usually natural sand is used as a fine aggregate at places where natural sand is not available crushed stone is used as fine aggregates. In our region fine aggregate can be found from bed of Krishna River. It conforms to IS 383 1970 comes under zone II.

**2.1.3 Coarse aggregate:** The material which is retained on BIS test sieve number 4 (4.75mm) is termed as coarse aggregate. The broken stone is generally used as a stone aggregate. Coarse aggregate used is locally available crushed angular aggregate of size 20mm and 10mm are used for this experimental work.

**2.1.4 Copper slag:** Copper slag is an industrial by-product material produced from the process of manufacturing copper. Copper slag used in this work was brought from Sterlite Industries Ltd (SIL), Kolkata, India.

**2.1.5 Ground Granulated Blast furnace Slag:** GGBS is a waste industrial by-product from the blast furnaces used to make iron. GGBS used in this work was brought from Duracem GGBS company, Auto Nagar, Visakhapatnam. The physical properties are given in table I & II.

**Table I: Physical properties of Copper slag & Natural sand**

| Physical Properties | Copper slag | Natural sand |
|---|---|---|
| Appearance | Black & glassy | Grainy& white |
| Type | Air cooled | Air cooled |
| Specific gravity | 3.91 | 2.5 to 2.8 |
| Percentage of voids | 43 | 47.8 |
| Bulk density g/cc | 2.08 | 2.7 |
| Fineness modulus | 3.47 | 2.65 |
| Water absorption % | 0.15 to 0.20 | 2.3 |
| Moisture content | 0.1 | 1.3 |

**Table II: Physical properties of GGBS & Cement**

| Physical Properties | GGBS | Cement |
|---|---|---|
| Colour | White | White & Grey |
| Water Absorption% | 0.75 | 4.35 |
| Specific Gravity | 2.77 | 3.13 |
| Fineness | 3% | 2% |

**2.2 Mix Design**

The mix proportion chosen for this study is M25 grade (1:1.3:2.95) with water-cement ratio of 0.45. In this test total 45 Cubes of standard size 150x150x150mm and 45 Cylinders of standard diameter 150mm and height 300mm and 45 Prisms of size 500x100x100mm were casted and cured for 7,14 and 28 days and tested as per code IS: 516-1959. The mix proportion chosen for this study is given in Table III.

**Table III: Mix proportion (Kg/m$^3$) and mix ratio**

| Water | Cement | Fine Aggregate | Coarse Aggregate (60% + 40%) |
|---|---|---|---|
| 191.6 | 425.77 | 534.73 | 1254.5 (752.7 + 508.8) |
| 0.45 | 1 | 1.3 | 2.95 |

## III. Tests And Results

The different tests conducted in laboratories are shown below. It consist mixing of concrete in the laboratory by replacing Copper Slag as fine aggregate with proportions (by weight) of Copper Slag added to concrete mixtures were as follows: 0% (for the control mix), 10%, 20%, 30% & 40% and GGBS as Cement with proportions (by weight) of GGBS added to concrete mixtures were as follows: 0% (for the control mix), 5%, 10%, 15% & 20% Concrete samples were prepared and cured in the laboratory, and are tested, to evaluate the concrete fresh and harden properties like compressive strength, Split tensile strength and flexural strength requirements.

**3.1 Slump cone test:** Slump cone test was conducted to determine the workability of concrete.

**Table IV: Workability in terms of Slump Cone test**

| Grade of concrete | Percentage of copper slag & GGBS added | SLUMP |
|---|---|---|
| M25 | 0 | 51 |
| | 10 & 5 | 53 |
| | 20 & 10 | 54 |
| | 30 & 15 | 56 |
| | 40 & 20 | 52 |

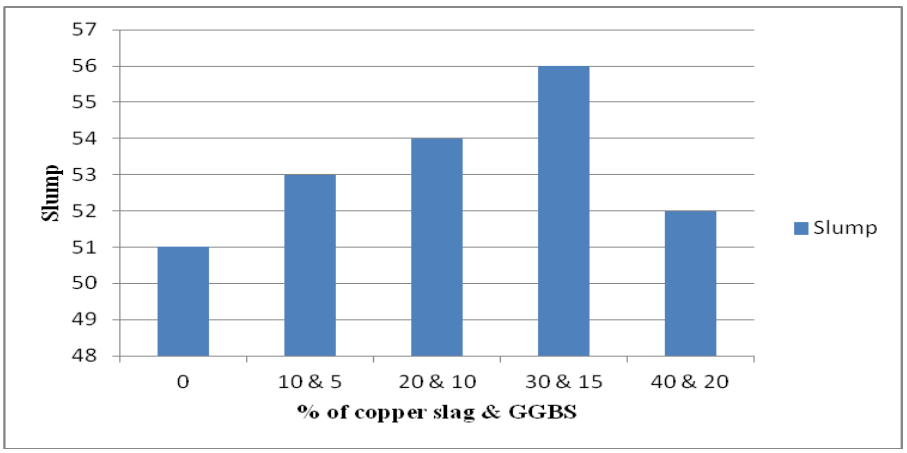


**Fig-1:** Variation of Slump

- From Fig 1, The variation of slump for the partial replacement of Fine aggregate with copper slag and Cement with GGBS increased in the order of 51, 53, 54 and 56 mm for 0%(CS & GGBS), 10%CS & 5%GGBS, 20%CS & 10%GGBS, 30%CS & 15%GGBS proportions and decreased by 52 mm for 40%CS & 20%GGBS proportions replacements respectively.

**3.2 Compaction factor test:** Compaction factor test was conducted to determine the workability of concrete

**Table V: Workability in terms of Compaction factor test**

| Grade of concrete | Percentage of copper slag & GGBS added | Compaction Factor |
|---|---|---|
| M25 | 0 | 0.88 |
| | 10 & 5 | 0.89 |
| | 20 & 10 | 0.91 |
| | 30 & 15 | 0.90 |
| | 40 & 20 | 0.90 |

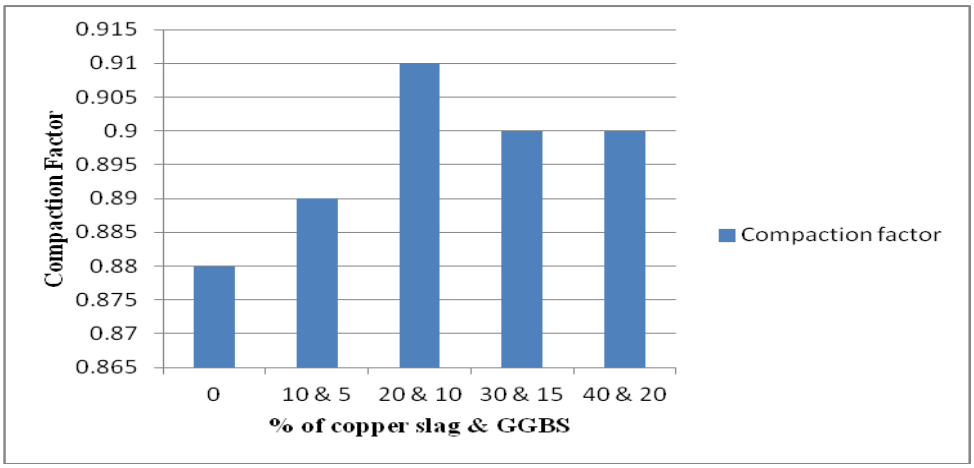


**Fig 2:** Variation of Compaction factor.

From Fig.2, The variation of compaction factor for the partial replacement of Fine aggregate with copper slag and Cement with GGBS increased in the order of 0.88, 0.89, 0.91, and 0.90 for 0%(CS & GGBS), 10%CS & 5%GGBS, 20%CS & 10%GGBS and 30%CS & 15%GGBS proportions and same by 0.90 for 40%CS & 20%GGBS proportions replacements respectively.

### 1.3 Compressive strength test

**Table VI: Compressive strength with different replacement percentages of Copper slag and GGBS**

| % of copper slag & GGBS replacement | 7 days | 14 days | 28 days |
|---|---|---|---|
| 0 | 19.06 | 25.6 | 31.36 |
| 10 & 5 | 20.10 | 26.4 | 32.53 |
| 20 & 10 | 21.30 | 27.3 | 33.41 |
| 30 & 15 | 22.41 | 28.1 | 34.33 |
| 40 & 20 | 19.80 | 26.06 | 32.02 |

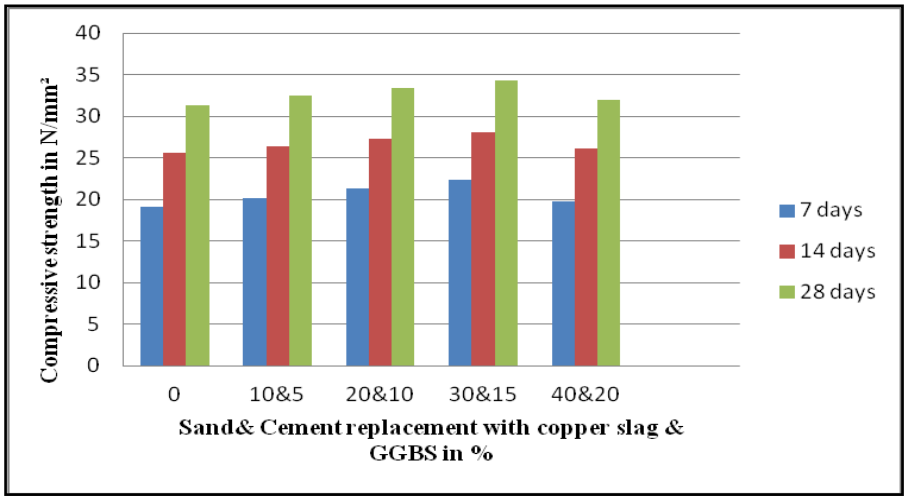


**Fig 3:** Compressive strength of concrete by partial replacing sand and cement with copper slag and GGBS

- From Fig.3, The compressive strength of concrete is increases by 9% with partial replacement of 30%CS & 15%GGBS in Fine aggregate & Cement, while compared with control Specimen.
- The compressive strength of concrete for the partial replacement of Fine aggregate with copper slag and Cement with GGBS increased in the order of 0%, 3.59%, 6.10%, 8.65% for 0%CS & GGBS, 10%CS & 5%GGBS, 20%CS & 10%GGBS, 30%CS & 15%GGBS proportions and decreased by 2.0% for 40%CS & 20%GGBS proportions replacements respectively.
- However compressive strength of concrete for the partial replacement of Fine aggregate with copper slag and Cement with GGBS for 40%CS & 20%GGBS does not decreased by control mix (0% CS &GGBS).

### 3.3 Split tensile strength test

**Table VI: Split tensile strength with different replacement percentages of Copper slag and GGBS**

| % of copper slag & GGBS replacement | 7 days | 14 days | 28 days |
|---|---|---|---|
| 0 | 2.18 | 2.56 | 3.51 |
| 10 & 5 | 2.30 | 2.68 | 3.56 |
| 20 & 10 | 2.41 | 2.74 | 3.67 |
| 30 & 15 | 2.48 | 2.82 | 3.72 |
| 40 & 20 | 2.25 | 2.58 | 3.53 |

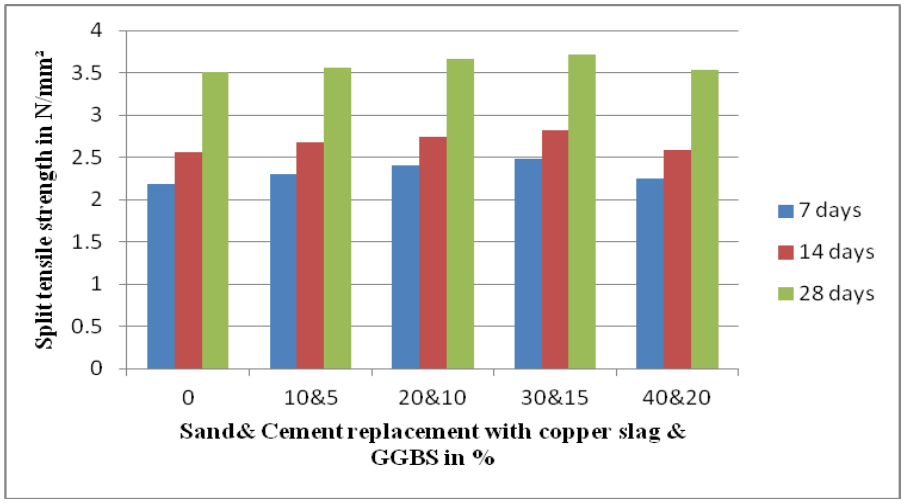


**Fig 4:** Split tensile strength of concrete by partial replacing sand and cement with copper slag and GGBS

- From Fig.4, The Split tensile strength of concrete is increases by 4% with partial replacement of 30%CS & 15%GGBS in Fine aggregate & Cement, while compared with control Specimen.
- The Split tensile strength of concrete for the partial replacement of Fine aggregate with copper slag and Cement with GGBS increased in the order of 0%, 1.52%, 4.47%, 5.75% for 0%CS & GGBS, 10%CS & 5%GGBS, 20%CS & 10%GGBS, 30%CS & 15%GGBS proportions and decreased by 0.8% for 40%CS & 20%GGBS proportions replacements respectively.
- However Split tensile strength of concrete for the partial replacement of Fine aggregate with copper slag and Cement with GGBS for 40%CS & 20%GGBS does not decreased by control mix (0% CS &GGBS).

### 3.4 Flexural strength test

**Table VII: Flexural strength with different replacement percentages of Copper slag and GGBS**

| % of copper slag & GGBS replacement | 7 days | 14 days | 28 days |
|---|---|---|---|
| 0 | 4.21 | 4.93 | 6.09 |
| 10 & 5 | 4.38 | 5.11 | 6.21 |
| 20 & 10 | 4.44 | 5.16 | 6.34 |
| 30 & 15 | 4.52 | 5.25 | 6.42 |
| 40 & 20 | 4.36 | 4.94 | 6.29 |

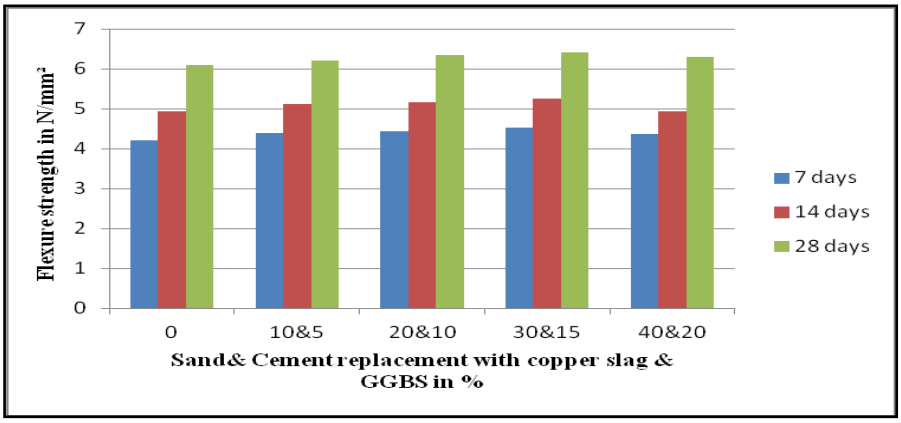


**Fig 5:** Flexural strength of concrete by partial replacing sand and cement with copper slag and GGBS

- From Fig.5, The Flexure strength of concrete is increases by 5.14% with partial replacement of 30%CS & 15%GGBS in Fine aggregate & Cement, while compared with control Specimen.
- The Flexure strength concrete for the partial replacement of Fine aggregate with copper slag and Cement with GGBS increased in the order of 0%, 2.0%, 3.9%, 5.1% for 0%CS & GGBS, 10%CS & 5%GGBS, 20%CS & 10%GGBS, 30%CS & 15%GGBS proportions and decreased by 3.28% for 40%CS & 20%GGBS proportions replacements respectively.
- However Flexure strength of concrete for the partial replacement of Fine aggregate with copper slag and Cement with GGBS for 40%CS & 20%GGBS does not decreased by control mix (0% CS &GGBS)

## IV. Conclusions

1. The compressive strength for partial replacement of fine aggregate with copper slag increased in the order of 13.3%, 5.03%, 3.39% & 2.03% for 10%, 20%, 30% & 40% partial replacements respectively and decreased by 11% for 50% partial replacement with respect to control specimen.
2. The split tensile strength for partial replacement of fine aggregate with copper slag increased in the order of 9.06%, 4.43%, 3.35% & 3.32% for 10%, 20%, 30% & 40% partial replacements respectively and decreased by 9.25% for 50% partial replacement with respect to control specimen.
3. The compressive strength for partial replacement of cement with GGBS decreased in the order of 1.4%, 2.13%, 1.18% & 2% for 5%, 10%, 15% & 20% partial replacements respectively with respect to control specimen.
4. The split tensile strength for partial replacement of cement with GGBS decreased in the order of 1.42%, 4.05%, 3.9% & 2.9% for 5%, 10%, 15% & 20% partial replacements respectively with respect to control specimen.
5. The compressive strength for partial replacement of fine aggregate with copper slag & cement with GGBS increased in the order of 3.59%, 6.10% and 8.65% for10%CS & 5%GGBS, 20%CS & 10%GGBS and 30%CS & 15%GGBS partial replacements respectively and decreased by 2% for 40%CS & 20%GGBS partial replacement with respect to control specimen.
6. The split tensile strength for partial replacement of fine aggregate with copper slag & cement with GGBS increased in the order of 1.52%, 4.47% and 5.75% for 10%CS & 5%GGBS, 20%CS & 10%GGBS and 30%CS & 15%GGBS partial replacements respectively and decreased by 0.8% for 40%CS & 20%GGBS partial replacement with respect to control specimen.
7. The flexural strength for partial replacement of fine aggregate with copper slag & cement with GGBS increased in the order of 2%, 3.9% and 5.10% for 10%CS & 5%GGBS, 20%CS & 10%GGBS and 30%CS & 15%GGBS partial replacements respectively and decreased by 3.28% for 40%CS & 20%GGBS partial replacement with respect to control specimen.

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