# EFFECT OF COPPER SLAG AND FLY ASH ON HIGH STRENGTH CONCRETE

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**ABSTRACT:**

An experimental investigation was conducted to study the effect of using copper slag as a fine aggregate and the effect fly ash as partial replacement of cement on the properties high strength concrete. Totally ten concrete mixtures were prepared. Five mixes containing different proportions of copper slag ranging from 0% (for the control mix) to 75%.Five mixes containing fly ash as partial replacement of cement ranging from 6% to 30%(all 5 mixes contains 50% copper slag as sand replacements) . Concrete mixes were tested for workability, density, compressive strength, tensile strength, flexural strength. The results indicate that there is a slight increase in the density of nearly 6% with the increase of copper slag content, whereas the workability increased with increase in copper slag percentage. Addition of up to 50% of copper slag as sand replacement yielded comparable strength with that of the control mix. However, further additions of copper slag caused reduction in the strength due to an increase of the free water content in the mix. Mix with 75% copper slag replacement gave the lowest compressive strength value of approximately 80 MPa, which is almost 4% more than the strength of the control mix. For this concrete containing 50% copper slag, fly ash is introduced in the concrete for better performance. Introduction of fly ash gave better results than concrete containing 50% copper slag.The strength has increased approximately 5% containing 25% fly ash and decreased with further replacements of cement with fly ash. Whereas, workability got increased with further increase in fly ash content. Therefore, it is recommended that 50% of copper slag can be used as replacement of sand and 18% fly ash can be used as replacement of cement in order to obtain high strength concrete.

Keywords: High Strength Concrete, Copper slag, fly ash.

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## 1. INTRODUCTION

High strength concrete (HSC) is widely used in the construction of high-performance structures such as high rise buildings, long span bridges, etc. So, it should have higher workability, good mechanical properties than those of conventional concrete. In order to achieve HSC with good mechanical properties, fly ash or/and silica fume which are considered as waste materials are used as one of the main ingredients. Concrete prepared with such materials showed improvement in workability compared to normal concrete. Use of some waste materials has been well documented in design specifications. New by-products and waste materials are being generated by various industries, dumping or disposal of these materials causes environmental and health problems. Therefore, recycling of waste materials has a great potential in concrete industry. Copper slag is an industrial by-product material produced in the process of manufacturing copper. It has been estimated that approximately 24.6 million tons of slag are generated from all copper industries every year. Copper slag possesses mechanical and chemical characteristics that is eligible as the material to be used in concrete as a partial replacement as a substitute for aggregates. copper slag has a favorable mechanical properties for aggregate use such as excellent soundness characteristics, good abrasion resistance and good stability .It also exhibits pozzolanic properties since it contains a low lime content and other oxides such as alumina , silica, and iron. Use of copper slag in the concrete industry as a replacement for fine aggregates can has the benefits of reducing the costs of disposal and helps protecting the environment.

## 2.REVIEW OF LITERATURE

**Caijun Shi, Christian Meyer, Ali Behnood (2008)** have investigated the use of copper slag in the production of cement, mortar and concrete as raw materials for clinker, cement replacement, coarse and fine aggregates. The use of copper slag in cement and concrete provides potential environmental as well as economic benefits for all related industries, particularly in areas where a considerable amount of copper slag is produced. This paper reviews the characteristics of copper slag and its effects on the engineering properties of cement, mortars and concrete.

**Wei Wu, Weide Zhang , Guowei Ma (2010)** This study investigated the mechanical properties of high strength concrete incorporating copper slag as a fine aggregate and concluded that less than 40% copper slag as sand substitution can achieve a high strength concrete that comparable or better to the control mix, beyond which however its behaviors decreased significantly. The workability and strength characteristics were assessed through a series of tests on six different mixing proportions at 20% incremental copper slag by weight replacement of sand from 0% to 100%. The results indicated that the strength of the concrete with less than 40% copper slag replacement was higher than or equal to that of the control specimen and the workability even had a dramatic growth.

**MostafaKhanzadi, Ali Behnood (2009)** presents the results of a study undertaken to investigate the feasibility of using copper slag as coarse aggregates in high-strength concrete. The effects of replacing limestone coarse aggregate by copper slag coarse aggregate on the compressive strength, splitting tensile strength, and rebound hammer values of high-strength concretes are evaluated in this work. Concrete mixtures containing different levels of silica fume were prepared with water to cementitious materials ratios of 0.40, 0.35, and 0.30. The percentages of the cement replacements by silica fume were 0%, 6%, and 10%. The use of copper slag aggregate compared to limestone aggregate resulted in a 28-day compressive strength increase of about 10–15%, and a splitting tensile strength increase of 10–18%. It can be concluded from the results of this study that using copper slag as coarse aggregate in high-strength concrete is technically possible and useful.

**Khalifa S. Al-Jabri , Makoto Hisada , Salem K. Al-Oraimi , Abdullah H. Al-Saidy (2009)** Had done an experimental program to investigate the effect of using copper slag as a replacement of sand on the properties of high performance concrete (HPC). Eight concrete mixtures were prepared with different proportions of copper slag ranging from 0% (for the control mix) to 100%. Concrete mixes were evaluated for workability, density, compressive strength, tensile strength, flexural strength. The results indicate that there is a slight increase in the HPC density of nearly 5% with the increase of copper slag content, whereas the workability increased rapidly with increases in copper slag percentage. Addition of up to 50% of copper slag as sand replacement yielded comparable strength with that of the control mix. However, further additions of copper slag caused reduction in the strength due to an increase of the free water content in the mix. The results also demonstrated that the surface waterabsorption decreased as copper slag quantity increases up to 40% replacement; beyond that level of replacement, the absorption rate increases rapidly. Therefore, it is recommended that 40 wt% of copper slag can used as replacement of sand in order to obtain HPC with good strength and durability properties.

**Khalifa S. Al-Jabri , Abdullah H. Al-Saidy, RamziTaha (2011)** An experimental investigation was conducted by them to study the effect of using copper slag as a fine aggregate on the properties of cement mortars and concrete. Various mortar and concrete mixtures were prepared with different proportions of copper slag ranging from 0% (for the control mixture) to 100% as fine aggregates replacement. Cement mortar mixtures were evaluated for compressive strength, whereas concrete mixtures were evaluated for workability, density, compressive strength, tensile strength, flexural strength and durability. The results obtained for cement mortars revealed that all mixtures with different copper slag proportions yielded comparable or higher compressive strength than that of the control mixture. Also, there was more than 70% improvement in the compressive strength of mortars with 50% copper slag substitution in comparison with the control mixture. A substitution of up to 40–50% copper slag as a sand replacement yielded comparable strength to that of the control mixture. However, addition of more copper slag resulted in strength reduction due to the increase in the free water content in the mix. Also, the results demonstrated that surface water absorption decreased as copper slag content increases up to 50% replacement.

## 3. MATERIALS USED

Inthepresentinvestigation materialsusedare

1. Ordinary Portland cement 53 Grade
2. Fly Ash as partial replacement to cement.
3. Copper slag as partial replacement to sand
4. Naturally available River sand as fine aggregate
5. Crushed Granite as coarse aggregate of size not greater than 10 mm
6. Master Glenium Sky super plasticizer(poly carboxylate based)
7. Water

## 4. MATERIAL PROPERTIES

(1) Ordinary Portland Cement (OPC) 53 grade conformingtoIS12269:1987is used in this work. The properties of used cement were

| | |
|---|---|
| TYPE | Ordinary Portland cement |
| Normal consistency | 32% |
| Specific Gravity | 3.13 |
| Compressive strength | 55.6 Mpa |

(2) Silicafume having specific gravity 2.68

(3) Fly Ash having specific gravity 2.2

(4) Thephysical propertiesoffineaggregate (riversand) were.

| | |
|---|---|
| Specific gravity – 2.65 | Water absorption – 1% |
| Fineness modulus – 2.68 | Maximum nominal size – 4.75 mm |

(5) Physical properties of copper slag were

| | |
|---|---|
| Specific gravity – 3.51 | Water absorption –0.18% |
| Fineness modulus – 2.53 | Maximum nominal size – 4.75 mm |

(6)Thephysical propertiesofCoarseaggregate (Crushed granite) were

| | |
|---|---|
| Specific gravity | 2.72 |
| Fineness modulus | 5.98 |
| Water absorption(%) | 0.3% |
| Maximum nominal size | 10 mm |

(7) Master Glenium Sky Super plasticizer (poly carboxylate based) having specific gravity of 1.08

## 5. LABORATORY TESTING PROGRAM

### 5.1. Mix design and sample preparation

The mix proportion chosen for this study is given in Table 1.Eleven concrete mixtures with different proportions of copper slag ranging from 0% (for the control mix) to 75% and fly ash 5% to 30%were considered as shown in Table 2. The materials were mixed in a rotating pan .The overall mixing time was about 4 min. The mixes were compacted using vibrating table. The slump of the fresh concrete was determined .The specimens were demoulded after 24 h, cured in water and then tested at room temperature at the required age. To determine the unconfined compressive strength , nine cubes (100 mm×100 mm × 100 mm) were cast for each mix, and three samples were tested after 7-days and 28-days of curing. six 100 mm diameter ×200 mm long cylinders were prepared for each mix in order to determine the after 7-days and 28-days tensile strength of concrete. Also, to determine the flexural strength (modulus of rupture) for each mix, three 100 mm×100 mm×500 mm prisms were cast and tested after 7-days and 28-days of curing.

### 5.2. Testing procedure

After curing, the following tests were carried out on the concrete specimens:

- 7-day, 28-day cube compressive strength test was conducted.
- 7-day,28-day cylinder tensile (splitting) strength test was done.
- 7-day,28-day flexural strength test was conducted.

**Table 1:Mix proportions (kg/m3)**

| Cement | Silica fume | sand | Coarse aggregate (10mm) | Water | w/c | Superplasticizer (l/m3) |
|---|---|---|---|---|---|---|
| 520 | 52 | 552.5 | 1161.59 | 130 | 0.25 | 7.8 |

**Table 2:Properties of high-strength concrete at 7- and 28-days of curing.**

| Mix | Mix Propotions | Densit | Slump | Compressive | Tensile Strength | Flexural Strength |
|---|---|---|---|---|---|---|

| No | | y (kg/m3 ) | (mm) | Strength (MPa) | | (MPa) | | (MPa) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 7 Days | 28 Days | 7 Days | 28 Days | 7 Days | 28 Days |
| M0 | Control (100% S) | 2460 | 48 | 62.83 | 78.66 | 4.695 | 4.93 | 8.04 | 8.87 |
| M1 | 90% S + 10% C.S | 2470 | 55 | 63.66 | 80.83 | 4.77 | 5.013 | 8.79 | 9.17 |
| M2 | 75% S + 25% C.S | 2520 | 66 | 65.66 | 83.3 | 4.85 | 5.17 | 9.25 | 9.41 |
| M3 | 50% S + 50% C.S | 2550 | 74 | 67.66 | 85.33 | 5.013 | 5.41 | 9.61 | 10.12 |
| M4 | 25% S + 75% C.S | 2591 | 82 | 62.66 | 79.83 | 4.69 | 5.01 | 8.58 | 9.34 |
| M5 | 50% S + 50% C.S+ 6% F.A | 2525 | 86 | 68.5 | 86.0 | 5.25 | 5.41 | 9.82 | 10.36 |
| M6 | 50% S + 50% C.S+ 12% F.A | 2526 | 91 | 69.3 | 87.16 | 5.33 | 5.49 | 9.88 | 10.38 |
| M7 | 50% S + 50% C.S+ 18% F.A | 2526 | 93 | 71.0 | 88.33 | 5.65 | 5.72 | 9.92 | 10.42 |
| M8 | 50% S + 50% C.S+ 24% F.A | 2528 | 97 | 68.83 | 86.66 | 5.25 | 5.41 | 9.86 | 10.36 |
| M9 | 50% S + 50% C.S+ 30% F.A | 2526 | 102 | 67.83 | 85.83 | 5.17 | 5.25 | 9.82 | 10.32 |

**Table 3: Chemical analyses of copper slag**

| Element /Compound | Analysis Range (%age) |
|---|---|
| Cu | 0.60 - 0.70 |
| Fe | 42 - 48 |
| $SiO^2$ | 26 - 30 |
| $Al^2O^3$ | 1.0 - 3.0 |
| S | 0.2 - 0.3 |
| CaO | 1.0 - 2.0 |
| MgO | 0.8 - 1.5 |
| $Fe^3O^4$ | 1.0 - 2.0 |
| As | 0.02 - 0.05 |
| Pb | 0.06 - 0.08 |
| Co | 0.01 - 0.03 |
| Cr | 0.02 - 0.04 |
| Zn | 0.2 - 0.4 |
| Ni | 0.005 - 0.008 |
| Chloride | 0.001 - 0.002 |
| PH | 7.0 - 7.5 |

## 6. RESULTS AND DISCUSSION

### 6.1. Chemical analyses and physical properties

Chemical analyses of copper slag are presented in Table 3. In comparison with the chemical composition of natural pozzolans of ASTM C618-99, the summation of the three oxides (silica, alumina and iron oxide) in copper slag is nearly 89%, which exceeds the 70% percentile requirement for Class N rawand calcined natural pozzolans. Therefore, copper slag is expected to have good potential to produce high quality pozzolans.

Tests to determine specific gravity and water absorption forcopper slag and sand were carried out in accordance with ASTM C128. Copper slag has a specific gravity of 3.51 which is higher than that for sand (2.65) and OPC (3.15) which may results in production of HSC with higher density when used as sand substitution. Also, the measured water absorption for copper slag was 0.18% compared with 1% for sand. This suggests that copper slag would demand less water than that required by sand in the concrete mix. Therefore, it is expected that the free water content in concrete matrix will increase as the copper slag content increases which consequently will lead to increase in the workability of the concrete.

### 6.2. Effect of copper slag and fly ash substitute on the workability and density of HSC

The effect of copper slag replacement as fine aggregates on the workability and density of high strength concrete is presented in Table 2 for different proportions of copper slag. The workability of concrete was assessed based on the measured slump of fresh concrete. It is clear from Table 2 that the workability of concrete increases with the increase of copper slag content in concrete mixes. For the control mixture (i.e. Mix 1), the measured slump was 48 mm whereas for Mix 5, with 75% replacement of copper slag, the measured slump was 82mm. This increase in the workability with the increase of copper slag quantity is due to the low water absorption characteristics of copper slag and its glassy surface. This increase in the workability may have beneficial effect on concrete in the sensethat concrete mixes with low water-to-cement ratios, for the same amount of sand replaced, can be produced which may have good workability, greater strength than the conventional HSC. However, it should be noted that mixes with high contents of copper slag (i.e. M4) showed signs ofbleeding and segregation which can have disadvantageous effects on concrete performance.Also Table 2 shows that there is general slight increase in thedensity of high strength concrete with the increase of copperslag quantity. The density of concrete was increased by almost 6%. This is mainly due to the higher specific gravity of copper slagwhich was 3.51 compared with sand which has a specific gravity of 2.65.And with the replacement of cement with fly ash also tends to increase in workability with a negligible increment in the density.

### 6.3 Hardened properties

Compressive strength of HSCwere measured according to ASTM C 39 by means of a compression testing machine. The test was conducted on three 100 mm cubes at the ages of 28 days normal water curing and the average of them was reported herein. Splitting tensile strength of the HSC was determined on 100 mm dia and200 mm height cylinder specimens at 7 and 28 days. The splitting tensile strength reported in the study was the average of two cylinders. Flexural strength of the HSC was determined on 500 mm x 100 mm x100 mm beam specimens. The test was conducted on one beam specimen after 7 and 28 days of normal water curing.

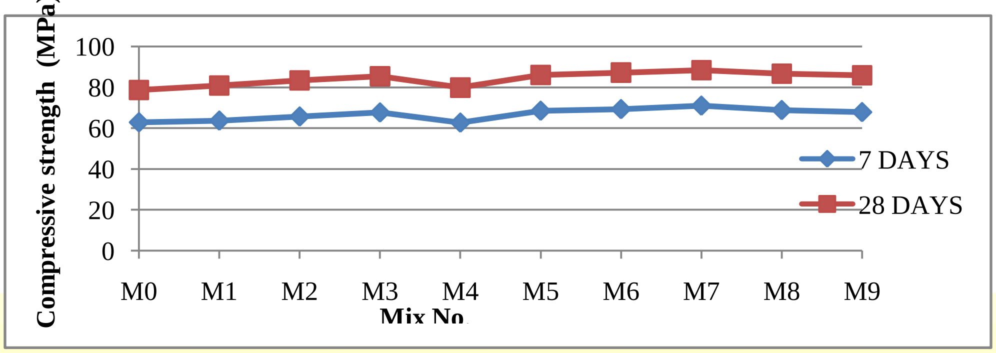


**Figure 1: Variation of Compressive Strength with different replacementsof Copper Slag and Fly Ash**

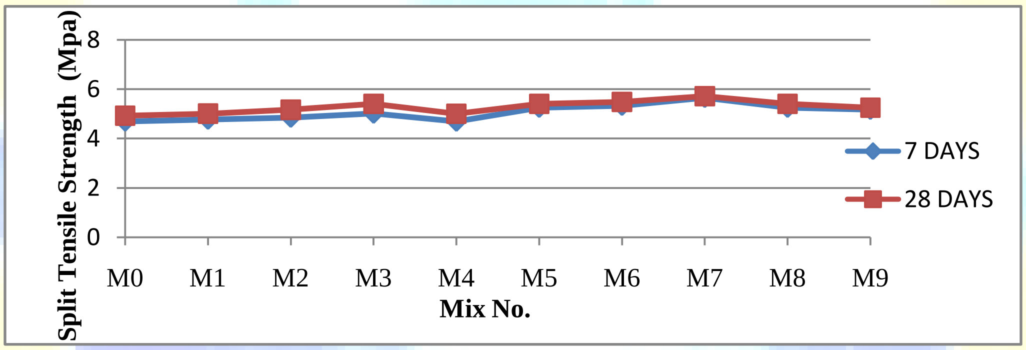


**Figure 2: Variation of Tensile Strength withdifferent replacements of Copper Slag and Fly Ash**

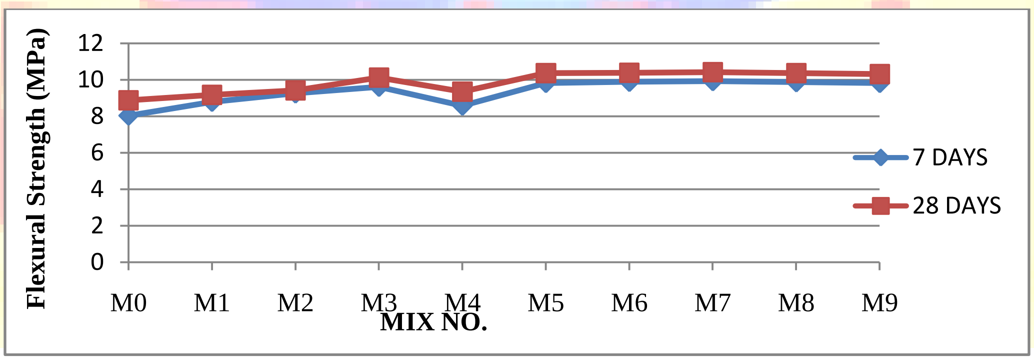


**Figure 3:Variation of Flexural Strength with different replacementsof Copper Slag and Fly Ash**

## 7. CONCLUSIONS

The following conclusions may be drawn from the present study:

1.The workability improved with the addition of copper slag. This increase in the workability with the increase of copper slag quantity is due to the low water absorption characteristics of copper slag and its glassy surface. With the replacement of cement with fly ash also tends to increase in workability with a negligible variation in the density.

2. Compared to the control mix, there was a slight increase in the HSC density of nearly 6% with the increase of copper slag content

3. Addition of up to 50% of copper slag as sand replacement yielded comparable strength with that of the control mix. However, further additions of copper slag caused reduction in the strength due to an increase of the free water content in the mix. Whereas, replacement of cement with fly ash caused increment in strength up to 18% (including 50% copper slag).

4. Mixtures with 75% copper slag replacement gave the less compressive strength value which was almost 7% lower than the strength of the HSC with 50% copper slag replacement.

5. Mixtures with 24% and 30% fly ash (including 50% copperslag) gave lowest compressive strength value which was almost 2% lower than the strength of HSC without replacement of fly ash.

6. It is recommended that 50% of copper slag can be used as replacement of sand and 18% fly ash can be used as replacement of cement in order to obtain HSC with good fresh and mechanicalproperties.

**8.References**


1. Khalifa S. Al-Jabri , Makoto Hisada b, Abdullah H. Al-Saidy , S.K. Al-Oraimi, “Performance of high strength concrete made with copper slag as a fine aggregate”, elsevier, Construction and Building Materials 23 (2009) 2132–2140.
2. Khalifa S. Al-Jabri , Abdullah H. Al-Saidy, RamziTaha, “Effect of copper slag as a fine aggregate on the propertiesof cement mortars and concrete”, Elsevier,Construction and Building Materials 25 (2011) 933–938.
3. BipraGorai, R.K. Jana ,Premchand, “Characteristics and utilisation of copper slag- a review”, Elsevier, Resources, Conservation and Recycling 39 (2003) 299- 313.
4. Khalifa S. Al-Jabri , Makoto Hisada , Salem K. Al-Oraimi , Abdullah H. Al-Saidy, “Copper slag as sand replacement for high performance concrete”, Elsevier, Cement & Concrete Composites 31 (2009) 483–488

5. K.S. Al-Jabri , R.A. Taha, A. Al-Hashmi, A.S. Al-Harthy, “Effect of copper slag and cement by-pass dust addition on mechanical properties of concrete” , Elsevier, Construction and Building Materials 20 (2006) 322–331.
6. MostafaKhanzadi, Ali Behnood , “Mechanical properties of high-strength concrete incorporating copper slag as coarse aggregate” , Elsevier, Construction and Building Materials 23 (2009) 2183–2188.
7. Wei Wu, WeideZhang ,Guowei Ma, “Optimum content of copper slag as a fine aggregate in high strength concrete”, Elsevier, Materials and Design 31 (2010) 2878–2883.
8. Caijun Shi, Christian Meyer , Ali Behnood, “Review Utilization of copper slag in cement and concrete”, Elsevier, Resources, Conservation and Recycling 52 (2008) 1115–1120.
9. IS: 12269-1987 “Specifications for 53-Grade Portland cement”, Bureau of Indian Standards, New Delhi, India.
10. IS 516:1959. Methods of tests for strength of concrete, New Delhi, India: Bureau of Indian Standard.
11. ACI 211.4R-93(Reapproved 1998), Guide for Selecting Proportions for High-StrengthConcrete with Portland Cement and Fly Ash.

**BIOGRAPHIES**

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