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Strength Determination of High Strength Concrete Blended with Copper Slag and Fly Ash

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Abstract: An experimental analysis was conducted to study the effects of using copper slag as a fine aggregate (FA) and the effect of fly ash as partial replacement of cement on the properties high strength concrete. In this analysis total ten concrete mixtures were prepared, out of which five mixes containing different proportions of copper slag ranging from 0% (for the control mix) to 75% were prepared and remaining five mixes containing fly ash as partial replacement of cement ranging from 6% to 30% (all mixes contains 50% copper slag as sand replacements). Concrete matrix were tested for compressive strength, tensile strength and flexural strength tests. Addition of copper slag as sand replacement up to 50% yielded comparable strength with that of the control matrix. However, further additions of copper slag, caused reduction in strength due to an increment of the free water content in the mix. Concrete mix with 75% copper slag replacement gave the lowest compressive strength value of approximately 80 MPa at 28 days curing period, 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 to achieve the better compressive, split and flexural strengths. It was also observed that, introduction of the fly ash gave better results than concrete containing 50% copper slag. When concrete prepared with 18 % of fly ash, the strength has increased approximately 4%, and strength decreased with further replacements of the cement with fly ash. Hence, it is suggested 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: Copper slag (CS), High Strength Concrete (HSC), fly ash (FA).

I. INTRODUCTION

High strength concrete (HSC) is widely used in the construction of high-performance structures, such as long span bridges and high rise buildings etc. So, it should have good mechanical properties than those of the conventional concrete. In order to achieve HSC with good mechanical properties, fly ash or/and silica fume are used as one of the main ingredients. Use of some waste materials has been well witnessed in the design specifications. Various by-products and waste materials are being generated by various industries, and dumping or disposal of these materials causes environmental and health problems. Therefore, recycling of these waste materials has a great potential in the field of concrete industry. Copper slag is an industrial by-product material, which is produced in the process of manufacturing of copper. It has been estimated that approximately 25 million tons of copper slag are generated from all copper industries every year. Copper slag possesses mechanical and chemical characteristics that makes it eligible as the material to be used in concrete as a partial replacement or as a substitute for aggregates. Copper slag has a favorable mechanical properties for aggregate use such as good abrasion resistance, excellent soundness characteristics and good stability also. It also exhibits some pozzolanic properties since it contains a low lime content and other oxides such as alumina, silica and iron. Use of copper slag in concrete industry as a replacement for fine aggregates can has the benefits of reducing the costs of disposal and also helps protecting the environment.

II. REVIEW OF LITERATURE

Abdullah H. Al-Saidy et al (2009) Made an experimental investigation to investigate the effect of using copper slag as a replacement of sand on the properties of high performance concrete (HPC).In this study, eight concrete mixtures were prepared with different proportions of copper slag ranging from 0% (for control mix) to 100%. They prepared, concrete mixes and these mixes were evaluated for density, workability, compressive strength, tensile strength, flexural strength. The results of this investigation indicate that there is a slight increase in the high performance concrete (HPC) density of nearly 5% with the increase of copper slag content, whereas the workability increased rapidly with increases in copper slag percentage. They found that, addition of up to 50% of copper slag as sand replacement yielded comparable strength increment 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 design concrete mix. The results also established that the surface water absorption decreased as copper slag quantity increases up to the mark of 40% replacement; beyond that level of replacement, the absorption rate increases rapidly. Therefore, it is recommended that 40% of copper slag (by weight) can used as replacement of sand in order to obtain HPC with good strength and durability properties.

Ali Behnood, Mostafa Khanzadi (2009) analyzed the results of a study undertaken to investigate the feasibility of using copper slag as coarse aggregates in high-strength concrete (HSC). The effects of swapping limestone coarse aggregate by copper slag coarse aggregate on the compressive strength and splitting tensile strength values of high-strength concretes are evaluated in this study. Concrete matrix containing different percentages of the silica fume were prepared with water to cementitious materials ratios of 0.40 and 0.35. The percentages of the cement alternates by silica fume were 0%, 6%, and 10%. The use of copper slag aggregate as compared to limestone aggregate resulted in a 28 days compressive strength increase of about 10 to 15%, and a splitting tensile strength increase of 10 to 18%. It can be established from the test results of this study that using copper slag as coarse aggregate in high-strength concrete (HSC) is technically possible and useful.

Caijun Shi et al (2008) made an study on the use of copper slag in the production of mortar, cement and concrete as raw materials for clinker, cement replacement, coarse and fine aggregates. In this study they use copper slag in concrete and cement, and found that the use of copper slag 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 study reviews the characteristics of copper slag and its effects on the engineering properties of mortars, cement and concrete.

Khalifa S. Al-Jabri et al (2011) made an investigation to study the effect of using copper slag as a fine aggregate on properties of cement mortars and concrete. In this investigation they prepared various mortar and concrete matrix with the 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 density, workability, compressive strength, tensile strength, flexural strength and durability also. The results obtained in this experiment for cement mortars revealed that all mixtures with different copper slag proportions yielded comparable or higher compressive strength than that of control mixture. Also, there was more than 70% increment in the compressive strength of mortars with 50% copper slag substitution in comparison with control mixture. A replacement of up to 40 to 50% copper slag as a sand replacement yielded comparable strength to that of control mixture. However, addition of more copper slag resulted in strength reduction due to the increase in the free water content in the design concrete mix. The results suggested that the surface water absorption decreased as copper slag content increases up to 50% replacement. Wei Wu and Weide Zhang (2010) investigated the mechanical properties of high strength concrete comprise 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 to the control mix, beyond which however its behaviors decreased significantly. The workability and strength characteristics were evaluated through a series of the tests on six different mixing proportions at 20% incremental copper slag by weight replacement of sand from 0% to 100%. The results of this investigation specified that the strength of the concrete with less than 40% copper slag replacement was higher than or equal to that of control specimen and the workability even had a dramatic growth.

III. MATERIALS USED

In this experimental investigation materials used are:

A. Ordinary Portland cement (OPC) 53 Grade
B. Fly Ash (FA) as a partial replacement to cement.
C. Copper slag (CS) as partial replacement to sand
D. River sand as fine aggregate
E. Crushed Granite as coarse aggregate of size less than 10 mm
F. Master Glenium Sky super plasticizer (poly carboxylate based), and
G. Water

IV. MATERIAL PROPERTIES

1) Ordinary Portland Cement (OPC) 53 grade conforming to IS 12269:1987 is used in this work. The properties of used cement were:

Type	Ordinary Portland cement
Normal consistency	34%
Specific Gravity	3.15
Compressive strength	56.3MPa

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2) Silica fume having specific gravity 2.69

3) Fly Ash having specific gravity 2.23

4) The physical properties of fine aggregate that is river sand were:

Specific gravity – 2.66	Water absorption – 1.3%
Fineness modulus – 2.67	Maximum nominal size – 4.75 mm

5) Physical properties of copper slag were:

Specific gravity – 3.53	Water absorption –0.19%
Fineness modulus – 2.52	Maximum nominal size – 4.75 mm

6) The physical properties of Coarse aggregate (Crushed granite) were:

Specific gravity	2.71
Fineness modulus	5.96
Water absorption (%)	0.34%
Maximum nominal size	10 mm

7) Master Glenium Sky Super plasticizer (poly carboxylate based) having specific gravity of 1.07.

V. LABORATORY TESTING PROGRAM

A. Mix Design and Sample Preparation

The mix proportions chosen for this study are given in Table1. In this experimental investigation, ten concrete matrix with different proportions of copper slag ranging from 0% to 75% and fly ash 6.0% to 30.0% were considered as shown in Table 2. The overall mixing time for this experiment was about 4 min. The specimens were demoulded from sampler after 24 hours, cured in water and then tested at room temperature at the required age. To determine the unconfined compressive strength, nine cubes (of dimensions 100 mm×100 mm × 100 mm) were cast for each mix, and three samples were tested after 7-days and 28-days of curing. They prepared six 100mm diameter ×200mm long cylinders for each mix in order to determine the after 7-days and 28-days tensile strength of concrete. Also, to determine the flexural strength for each mix, three (100 mm×100 mm×500 mm) prisms were cast and tested after 7-days and 28-days of curing.

B. Testing Procedure

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

1) 7 day and 28 day cube compressive strength tests were conducted.

2) 7 day and 28 day cylinder tensile (splitting) strength test was done.

3) 7 day and 28 day flexural strength test was conducted.

Table 1: Mix proportions (kg/m^3)

Cement	Silicafume	sand	Coarse aggregate(10mm)	Suerplasticizer (l/m^3)
520	52	552.52	1160.63	7.8

Table 2: Mix Proportion for different samples

Mix No	Mix Propotions
S-0	Control (100% S)
S-1	90% S + 10% C.S
S-2	75% S + 25% C.S
S-3	50% S + 50% C.S
S-4	25% S + 75% C.S
S-5	50% S + 50% C.S+ 6% F.A
S-6	50% S + 50% C.S+ 12% F.A
S-7	50% S + 50% C.S+ 18% F.A
S-8	50% S + 50% C.S+ 24% F.A
S-9	50% S + 50% C.S+ 30% F.A

VI. RESULTS AND DISCUSSION

A. *Physical Properties*

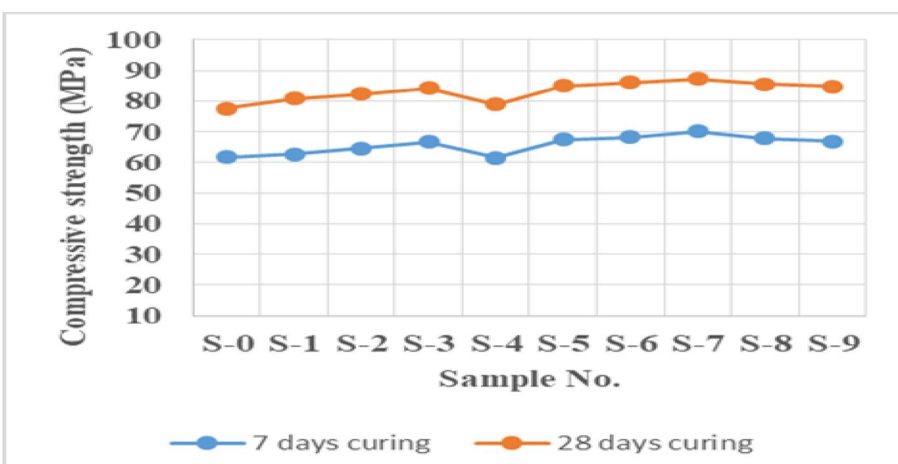
Various tests to determine specific gravity and water absorption for copper slag and sand were carried out. In this investigation, copper slag has a specific gravity of 3.53 which is higher than that for sand (2.66) and OPC (3.15) which may results in production of HSC with higher density when used as sand substitution. Also, the measured water absorption for copper slag was found 0.19% compared with 1.3% for sand. This result revealed that copper slag would demand less water than that required by sand in the concrete matrix. Therefore, it is expected that the free water content in concrete mix will increase as the copper slag content increases which consequently will lead to increase in workability of the concrete.

B. *Hardened Properties*

Compressive strength of High Strength Concrete (HSC) were measured according to ASTM C 39 by means of a compression testing machine. The tests were 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 HSC was determined on 100 mm diameter and 200 mm height cylinder specimens at 7 and 28 days. The splitting tensile strength reported in this study was the average of two cylinder specimens. Also, the 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 period.

VII. GRAPHS

1) *Graph 1: Compressive Strength of Concrete*



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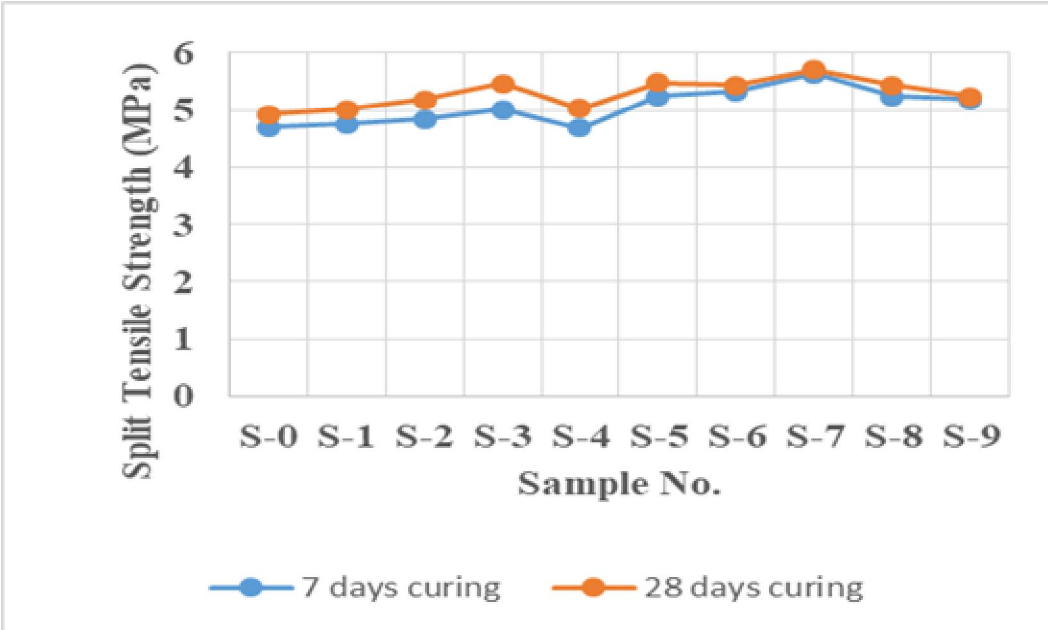
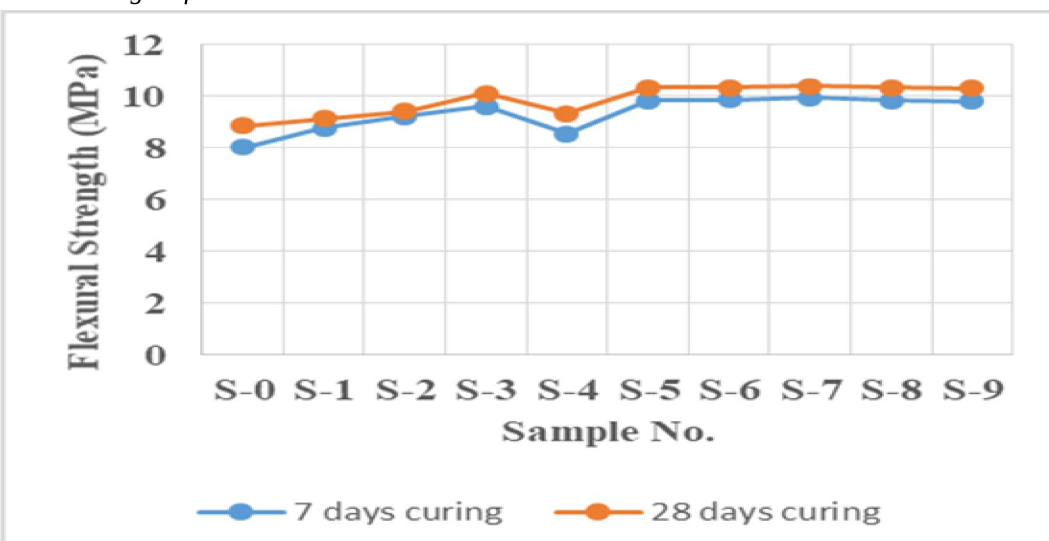
2) Graph 2: Split Tensile Strength of Concrete



3) Graph 3: Flexural Strength of Concrete



VIII. CONCLUSIONS

The following conclusions may be given from the present study:

A. Addition of copper slag up to 50%, as sand replacement yielded comparable strength with that of control mix. However, further addition of copper slag caused reduction in strength due to an increase of the free water content in the mix. Whereas, replacement of cement with fly ash resulted increment in strength up to18% (including 50% copper slag).

B. Concrete mixtures with 75% copper slag replacement gave the less compressive strength, which was almost 7% lower than the strength of the HSC with 50% copper slag replacement.

C. Concrete mixtures with 24% and 30% fly ash (including 50% copper slag) gave lowest compressive strength, which was almost 2% lower than the strength of HSC without replacement of fly ash.

D. It can be concluded that 50 % of copper slag can be used as replacement of sand and 18% of fly ash can be used as replacement of cement in order to obtain the High Strength Concrete (HSC) to achieve good, fresh and mechanical properties.

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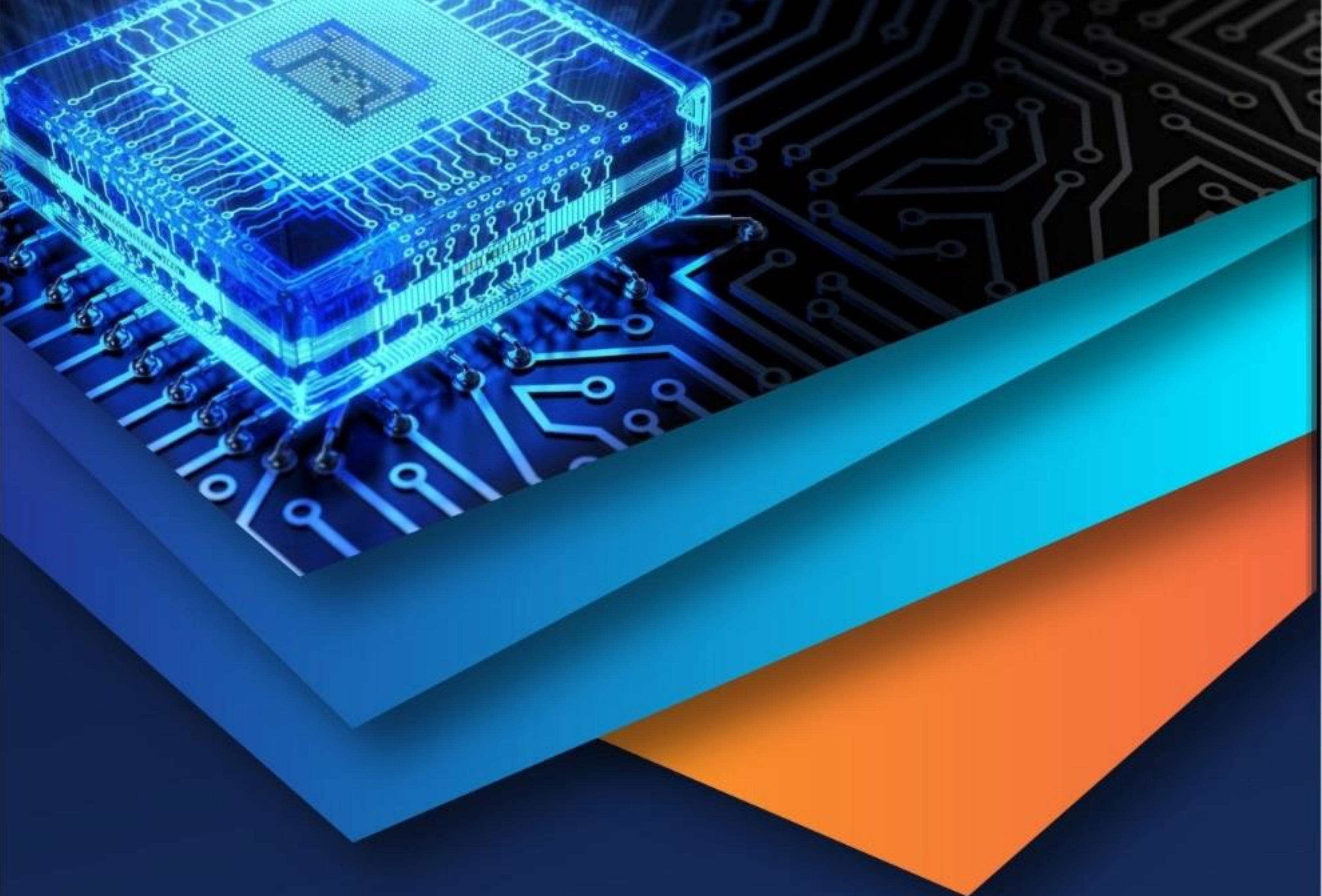

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