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Performance of Copper Slag as Fine Aggregate in High Strength Fly Ash Concrete

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Abstract – *One of the major problems arising from the industrial development is the accumulation of waste materials and it's disposal. Accumulation of industrial waste is a cause of environmental pollution too. The major environmental issues associated with the cement industry is it's emission of carbon dioxide along with other gases to atmosphere. The use of riverbed sand for the construction purpose has led to the excessive sand mining there by creating major environmental issues. Copper slag and fly ash are the waste materials developed from the copper industries and coal based thermal power plants. In this experimental investigation, M60 grade of concrete was studied with fly ash partially replacing cement by 20% and copper slag replacing sand by 6 percentages, i.e, 0%, 20%, 40%, 60%, 80% and 100%. The w/c used was 0.3. The various aspects studied were workability, compressive strength, split tensile strength and temperature effect. It was found that concrete with 20% fly ash (replacing cement) and 40% copper slag (replacing sand) showed better results considering all aspects.*

Key Words: **Fly Ash, Copper Slag, Workability, Compressive Strength, Split Tensile Strength, Temperature Effect.**

1. INTRODUCTION

The demand for natural sand is extremely high in the developing countries due to the large usage of concrete to satisfy the rapid infrastructure growth. In India, there is a serious threat to environment and society due to large usage of natural sand deposits. Rapid extraction of sand from riverbed causes many problems like loss of vegetation, lowering of water table and it causes disturbance to aquatic life. Also, the cost of sand has increased due to its demand.

Copper slag is a by-product formed during the manufacturing of copper. Approximately 2.2 to 3.0 tons of copper slag is formed while producing one ton of copper. As refineries draw metal out of copper ore, the residue contains a large mass of rock, non-metallic dust, and soot. All these materials combined to form copper slag. This slag can be used as a replacement of fine aggregate as well as cement in concrete.

Air pollution is one of the major drawbacks of cement industry. The production of cement releases large amount of carbon dioxide, in addition to the cement dust, into air. Fly ash is a by-product obtained by the combustion of pulverized coal in coal based thermal power plant. The quantum of fly ash production per year is huge that its disposal has become a major challenge. Fly ash has chemical properties like cement. Hence it can be used as a partial substitute of the binder material in concrete.

2. PROBLEM DEFINITION

The increase in construction industry leads to the high utilization of the natural sand. Also, sand is expensive to procure. Cement industries are emitting tons of carbon dioxide into atmosphere. The accumulation of industrial waste is a big crisis now a day. The usage of industrial wastes as a substitution to cement and natural sand provide solution to these crises.

This paper is about the study of M60 grade of concrete with fly ash and copper slag as a partial replacement of cement and sand, respectively. In this investigation, fly ash was partially replaced with cement by 20% and copper slag with fine aggregate in six variations, i.e, 0%, 20%, 40%, 60%, 80% and 100%. This copper slag - fly ash concrete was then compared with conventional concrete in terms of workability, compressive strength and split tensile strength. It's durability at high temperature was also checked.

3. LITERATURE REVIEW

J. Karthick et. al, (2014) [1] In this investigation M20 grade concrete was studied by replacing cement with fly ash by 30% and sand with copper slag by 6 proportion, i.e, 0%, 10%,20%, 30%, 40% and 50%. The specimens casted were studied for compression, split tensile and flexural strength. The specimen with 30% fly ash and 40% copper slag gave the best results when compared with normal concrete.

Binaya Patnaik et. al, (2014) [2] This experimental investigation was carried out for M20 grade of concrete. Various mixes were formed with partial replacement of Fine Aggregate (Sand) with Copper Slag by 0%, 10%, 20%, 30%, 40% and 50%. Compressive Strength at the ages of 7, 28 &90 days for these mixes were investigated. It was found that the compressive strength of concrete was comparable to the control mix up to 40% of copper slag substitution.

J. Ramesh Kumar et. al. (2015) [3] This was an experimental investigation on high strength concrete by replacing fly ash with cement and copper slag with sand. The parameters studied were compressive strength, split tensile strength and flexural strength. The replacement of copper slag with sand by 10%, 25%, 50% and 75% were studied first. The mix containing 50% copper slag and 50% sand gained maximum strength when compared to normal concrete. The effect of fly ash on concrete was studied by keeping the fine aggregate as a combination of 50% copper slag and 50% sand. The fly ash variation level taken were 6%, 12%, 18%, 24% and 30%. It was found that the concrete mix with 18% fly ash and 50% copper slag gave the best result.

M. Pavan Kumar et. al, (2015) [4] Here M25 grade concrete was studied by replacing cement with GGBS and sand with copper slag. Cement was replaced with GGBS by 0% (without GGBS), 5%, 10%, 15%, and 20% by weight of cement and copper slag with sand by 0% (without Copper slag), 10%, 20%, 30%, and 40% by weight of sand. The various properties studied were compressive strength, split tensile strength and flexural strength. The concrete mix with 15% GGBS and 30% copper slag gave the best result when compared with the normal concrete.

4. MATERIALS USED

4.1 Ordinary Portland Cement

Ordinary Portland cement of grade 53 was used in this study. The specific gravity of OPC used was 3.09.

4.2 Fine Aggregate

In this work natural river sand was used. The sand was tested for their physical properties as per relevant IS codes and is given in the Table-1.

Table -1: Physical Properties of Fine Aggregate

Characteristics	Value
Specific gravity	2.56
Zone	Belong to grading zone II of IS: 383 1970

4.3 Coarse Aggregate

Coarse aggregate used in this study were 20mm downsize. The properties were tested as per IS-2386. The specific gravity of coarse aggregate used was 2.64.

4.4 Copper Slag

The copper slag used in this study was obtained from Sterlite Industries, Tuticorn Tamil Nadu. The specific gravity of Copper Slag used was 3.9.

4.5 Fly Ash

Class C fly ash was used in this work. The physical properties of fly ash are given in Table -2.

Table -2: Physical Properties of Fly ash

Characteristics	Value
Specific gravity	2.10
Particle size	90 Microns
Colour	Dark grey

4.6 Superplasticizer

The Superplasticizer used in this work was CONPLAST SP430 which will improve the workability of concrete without affecting its strength properties.

5. MIX PROPORTION

Mix design was done as per IS: 10262:2009. The mix ratio used in this study was 1: 1.44: 2.19 with 0.3 w/c ratio.

5.1 Mix Designation

Table -3 shows the mix designation used in the study

Table -3: Mix Designation

Mix Designation	Description (Fly ash replacing cement and copper slag replacing sand)
CC	Conventional Concrete
CF1	20% Fly Ash + 0% Copper Slag
CF2	20% Fly Ash + 20% Copper Slag
CF3	20% Fly Ash + 40% Copper Slag
CF4	20% Fly Ash + 60% Copper Slag
CF 5	20% Fly Ash + 80% Copper Slag
CF 6	20% Fly Ash + 100 % Copper Slag

6. EXPERIMENTAL INVESTIGATIONS AND DISCUSSIONS

6.1 Workability

Slump test was conducted to find the workability of concrete. A slump of 100 ± 5 mm was maintained. The result is shown in the Table - 4. It was observed that the slump valve increased with increase in copper slag up to 60%. Admixture dosage was observed to reduce as the copper slag percentage increase. The spherical shape of the fly ash and copper slag reduces the friction between the particles thereby giving more mobility to the mixture.

Table -4: Slump Test

Trail Mixes	Admixture dosage	Slump Value
CC	1.4 %	99 mm
CF1	1.2 %	101 mm
CF2	1.2 %	102 mm
CF3	1.2 %	104 mm
CF4	1.2 %	105 mm
CF5	0.8 %	96 mm
CF6	0.8 %	97 mm

6.2 Compressive Strength

Compressive strength test was carried out on cubes of size 150mm after 7 and 28 days of water curing. The test was conducted in the compression testing machine as per IS 516.

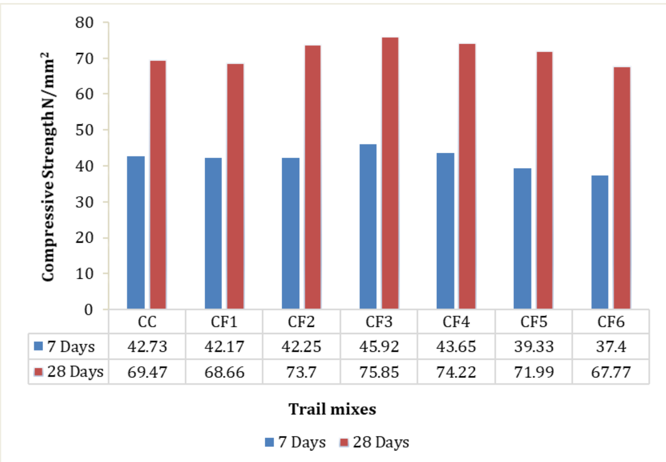

Chart -1: Compressive strength at 7 and 28 days

The compressive strength of copper slag-fly ash mixes was determined and compared with conventional concrete for 7 and 28 days of curing period. The Chart-1 shows the strength value obtained during the investigation. A rise in compressive strength was observed by the addition of copper slag. The maximum value was obtained for the mix CF3 for both curing periods. The strength obtained for CF3 mix at 7 and 28 days was 7.5 % and 9% more when compared to control mix. The summation of oxides of iron, silica and alumina is nearly 95% in copper slag which may be reason for the increase in strength. A reduction in strength was observed beyond 40% replacement. The copper slag has a lower water absorption property when compared to sand. Hence the free water content in the mix increases as the copper slag percentage increases. This must be the reason for the reduction of strength beyond 40% replacement of copper slag.

6.3 Split Tensile Strength

This test was conducted on cylindrical specimen of size 150mm(dia.) x 300mm(height) using compression testing machine. The test was done as per IS 5816 after 7 and 28 days of water curing.

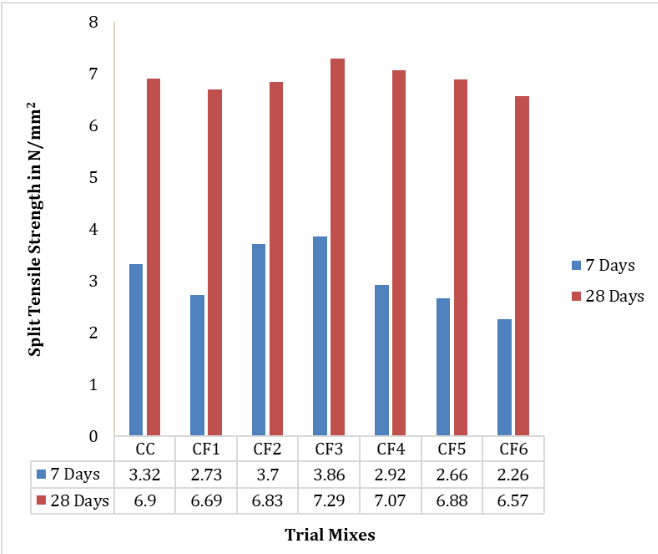

Chart -2: Split tensile strength at 7 and 28 days

Chart-2 shows the split tensile strength of copper slag-fly ash concrete. The addition of fly ash and copper slag increase the split tensile strength of concrete. The split tensile strength of the mixes gradually increased up to CF3 mix, after which a reduction of strength was found. CF3 mix gained maximum strength. An increase of 6% in split tensile strength was observed for CF3 mix at 28 days when compared to CC.

6.4 Temperature Effect

The test specimen used for the temperature effect was cylinder of size 150mm (dia) x 300mm (height). After 28 days of water curing, the specimen was taken out, dried and kept in an oven at 200°C for 24 hours. The effect of temperature in strength and weight was found out. The loss in strength and weight due to temperature effect can be calculated using the formula,

$$\% \text{ Loss in strength} = [(fc - fc_1)/fc] \times 100$$

$$\% \text{ Loss in weight} = (W_1 - W_2/W_1) \times 100$$

Where,

fc = split tensile strength at 28 days of age

fc_1 = split tensile strength after keeping in oven at 200^{0}C.

W_1 = Weight of specimen after 28 days of curing

W_2 = Weight of specimen after keeping in oven at 200^{0}C.

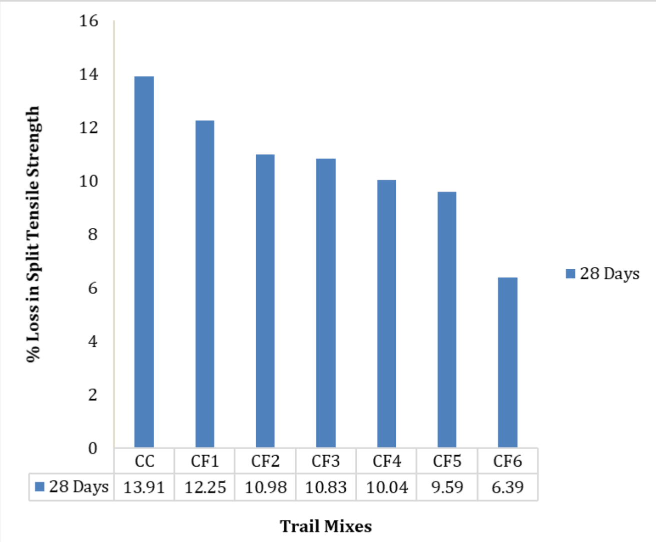

Chart -3: % Loss in Split Tensile Strength

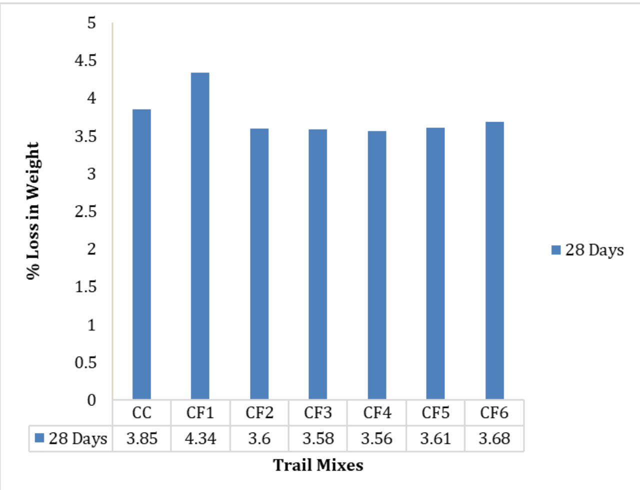

Chart -4: % Loss in Weight

The effect of temperature in strength and weight is shown in Chart 3 and 4 respectively. It was found that the percentage loss in weight and strength reduces as the copper slag content increases. The reduction in strength and weight may be due to the loss of water content from the concrete. The water reduction makes concrete more brittle and high temperature gives small cracks on the surface of concrete which may leads to loss in weight and strength.

7. CONCLUSIONS

- Fly ash and copper slag can be used as a partial replacement of cement and fine aggregate, respectively.
- There was an increase in the workability of concrete with increase in the copper slag content.
- The superplasticizer quantity was found to be decreasing as the copper slag quantity increases.
- An increase in compressive strength and tensile strength was observed by the addition of copper slag.
- Maximum strength was observed for CF3 mix for both compressive and split tensile strength test.
- The compressive strength of copper slag-fly ash concrete was comparable to CC in all ages.
- Compressive strength, when compared with CC, at 28 days was found to be increased by 9% for CF3 mix.
- 6% increase in split tensile strength was observed for CF3 mix after 28 days of water curing.
- The increase in copper content in concrete gives more resistance to high temperature.
- Considering all aspects, CF3 mix shows better performance, ie, concrete replacing cement with 20% fly ash and fine aggregate with 40% copper slag can be considered as the optimum percentage replacement.
- The use of fly ash and copper slag resulted in an environment friendly concrete. It also reduces the disposal problems of such industrial waste products.

REFERENCES

[1] J. Karthick, S.Suriya Prakash, H. Jeniston Davidraj "Experimental Study on Strength Characteristics on M20 Concrete with Partial Replacement of Cement with Fly ASH and Replacement of Fine Aggregate with Copper Slag" International Journal of Advanced Research in Eduation Technology, Vol. 1, Issue 1, PP 26-29, July-September 2014.

[2] Binaya Patnaik, Seshadri Sekhar T and Srinivasa Rao "An Experimental Investigation on Optimum Usage of Copper Slag as Fine Aggregate in Copper Slag admixed Concrete" International Journal of Current Engineering and Technology, Vol.4, No.5, October 2014.

[3] J. Ramesh Kumar, K. V. Ramana "Use of Copper Slag and Fly Ash in High Strength Concrete" International Journal

of Science and Research, Vol. 4 Issue 10, PP 777- 781, October 2015.

[4] M. Pavan Kumar, Y.Mahesh " The Behaviour of Concrete by Partial Replacement of Fine Aggregate with Copper Slag and Cement with GGBS - An Experimental Study" IOSR Journal of Mechanical and Civil Engineering , Vol. 12, Issue 3, PP 51-56, May-June 2015.

[5] Wei wu, Zhang.w, and Ma.G, "Optimum Content of Copper Slag as Fine Aggregate in High Strength Concrete", Material Design, vol.31, No.6, pp.2878-2883, 2010.

[6] R RChavan and D B KulkarniPaper on "Performance of Copper Slag on Strength Properties as Partial Replace of Fine Aggregate in Concrete Mix Design" International Journal of Advanced Engineering Research and Studies. E-ISSN: 2249-8977, 2013.

[7] IS 456: 2000, Plain and Reinforced Concrete.

[8] IS: 10262-2009, Concrete Mix Proportioning - Guidelines (First Revision).

[9] IS: 10262-2009, Concrete Mix Proportioning - Guidelines (First Revision).

[10] IS: 2386:1963, Tests on Aggregates.

[11] IS: 516-1959 (Reaffirmed 2004), Indian Standard Method of Test for Strength of Concrete.

[12] IS: 383-1970 (Reaffirmed 2007), Indian Standard Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete.

[13] IS: 5816-1999 (Reaffirmed 2004), Indian Standard Splitting Tensile Strength of Concrete - Method of Test