

# Experimental Study on Mechanical Properties of Concrete Using Copper Slag as a Replacement Material of Fine Aggregate with Fly Ash (20%) in Cement

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**ABSTRACT:** In this study, effects of copper slag on strength were experimentally investigated. The Study focus on partial replacement of fine aggregate by copper slag in M<sub>30</sub> grade concrete. The experimental programme was developed to evaluate the effect of several percentages of sand substitution in mortars. For mortars 30, 40 and 50% of sand replacement by volume was studied. This paper presents a detailed experimental study on compressive strength, split tensile strength and flexural strength at an age of 7, 14 and 28days of water curing. Results obtained so far indicated that an increase of strength occurs when the slag content increases for particular percentage. Additionally, 20% of fly ash is constantly added to the cement as binding agent to give workability to the concrete. As a conclusion, the use of copper slag as sand replacement seemed to be practical option.

**KEYWORDS:** copper slag, fly ash, compressive strength, split tensile strength, flexural strength.

## I. INTRODUCTION

Aggregate is the main constituent of concrete, occupying more than 70% of the concrete mix. In many countries, there is a scarcity of natural aggregates that is suitable for construction, whereas in other countries the consumption of aggregates has increased in recent years, due to increases the construction industry. In order to reduce depletion of natural aggregate due to construction, artificially manufactured aggregates and some industrial waste materials can be used as alternatives. Copper Slag (CS), produced during matte smelting and copper conversion was previously considered waste and disposed as landfill. It has been estimated that for every ton of copper production about 2.2 – 3 tons of slag are generated. Slag's containing < 0.8% copper are either discarded as waste or sold cheaply. Processed, air-cooled, and granulated CS has a number of favorable mechanical properties for aggregate use, including excellent soundness characteristics and good abrasion resistance. Alter studied the effect of CS on the environment on the basis of basal convention and characterized it as non – hazardous. Carried out toxicity characterization and long term stability studies on CS and reported that the slag samples are non – toxic and pose no environmental hazard additionally poor leach ability of the slag metals assure long term stability, even in extreme climates. The tests indicate that the heavy metals present in the slag are stable and are not likely to dissolve significantly even through repetitive leaching under acid rain.

## II. MATERIAL PROPERTIES

### 2.1 MATERIAL USED

The materials used for making fly ash based copper slag concrete specimens are copper slag as the source material, fine aggregates, coarse aggregate, fly ash, cement and water.

### 2.2 COPPER SLAG

Copper slag, a by-product from copper smelting industry, is widely used as an abrasive material to remove rust, old coating and other contamination in dry abrasive blasting which is an expensive process and results in significant amounts of particulate emissions and spent abrasive. This paper presents models developed to improve productivity and consumption of copper slag as functions of blast pressure, abrasive feed rate, and surface contamination. These models will help industries in selecting optimum process conditions for maximum efficiency and to achieve cleaner production by consuming less materials and energy resources. In addition, the models will greatly assist in evaluation of the life cycle costs for use of copper slag in dry abrasive blasting.



Fig 4.2 Copper Slag

Table 2.1: Properties of Copper Slag

S.No	Physical properties	Result
1.	Specific gravity	3.86
2.	Physical form	Powder
3.	Colour	Black

### 2.3 FLY ASH

Fly ash is like a slag an industrial waste that is widely used as mineral admixture in the cement and concrete industry the chemical composition of fly ash depends on the composition of the original coal ash. Fly ash improves concrete's workability, pump ability cohesiveness, finish, ultimate strength as well as solves many problems experienced with concrete today and all for less cost. The properties of fly ash are shown in Table 2.2.

Table 2.2: Properties of fly ash

S.No	Physical properties	Result
1.	Specific gravity	2.14
2.	Physical form	Powder
3.	Size (Micron)	0.1
4.	Colour	Dark grey



**Fig 4.1 Fly Ash**

### III. Mix Design

#### 3.1 GENERAL

The process of selection suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required strength and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in two states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability therefore becomes of vital importance.

#### 3.2 MIX PROPORTIONS

Cement	= 394 Kg/m <sup>3</sup>
Fly Ash	= 98.5 Kg/m <sup>3</sup>
Water	= 197 Lit/ m <sup>3</sup>
Fine aggregate	= 743.58 Kg/m <sup>3</sup>
Coarse aggregate	= 934.34 Kg/m <sup>3</sup>

The table 3.1 shows the mix proportion of concrete.

**Table 3.1 Mix proportion**

Mix proportions	Cement kg/m <sup>3</sup>	Fine Aggregate kg/m <sup>3</sup>	Coarse Aggregate kg/m <sup>3</sup>	Water kg/m <sup>3</sup>	Fly ash kg/m <sup>3</sup>	Copper Slag kg/m <sup>3</sup>
Mix 1 (0%)	394	743.58	934.34	197	98.5	0
Mix 2 (30%)	394	520.52	934.34	197	98.5	322.01
Mix 3 (40%)	394	446.15	934.34	197	98.5	429.35
Mix 4 (50%)	394	371.79	934.34	197	98.5	536.69

### IV. EXPERIMENTAL TEST

#### 4.1 MECHANICAL PROPERTIES

##### 4.1.1 Compressive Strength Test

For each series of test, a set of standard size of cube and cylinder were made. The size of cube is 150 mm x 150 mm x 150 mm, depending on the type of test. The cube will be tested in CTM in accordance with the test procedures given in the Indian Standard, Method of Testing Concrete – Determination of the compressive strength of concrete specimens.



**Fig 4.1 Compressive Strength**

#### 4.1.2 Split Tensile Strength Test

Split tensile strength of concrete is usually found by testing plain concrete cylinders. Cylinders of size 150mm x 300 mm were casting using M<sub>25</sub> grade concrete. Specimens with Conventional Concrete and SCC of two different percentages were casted. During casting the conventional concrete cubes were manually compacted using tamping rods. After 24hours, the specimens were removed from the mould and subjected to water curing for 7, 14, 28 days. After curing, the specimens were tested for compressive strength as per IS: 5816-1999 using a calibrated compression testing machine of 2000KN capacity.

Two packing strips of plywood 3mm thick were provided between the specimen one at top and another at bottom. The specimen was placed on the plywood strip and aligned so that, the central horizontal axis of the specimen is exactly perpendicular to the load applying axis. The second plywood strip was placed length wise on the cylinder and the top platen was brought down till it touched the plywood. The load was applied without shock and increased continuously until the resistances of the specimen to the increasing load broke down and no greater load can be sustained.

$$\text{Tensile strength of concrete } f_t = \frac{2p}{\pi dl}$$

$$\text{Where, } P = \text{Maximum load in N applied to the specimen}$$

$$L = \text{Measured length in cm of the specimen}$$

$$D = \text{Measured diameter in cm of the specimen}$$



**Fig 4.2 Split Tensile Strength**

#### 4.1.3 Flexural Strength Test

The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress, here given the symbol  $f_{cr}$ . The flexural strengths of the respective specimens have been obtained from the flexural tests performed on the prism specimens of size 100mm x 100mm x 500mm. The flexural strength are tested using a two point loading frame machine as per standard as shown in figure 4.2.

The loading must be applied centrally and without subjecting the specimen to any tensional stresses and restraints. The axis of the specimen shall be carefully aligned with the axis of the loading device. The load shall be applied without any shock and increasing continuously at specified rate.

#### Calculation

The flexural strength of the specimen was expressed as the modulus of rupture,  $f_{br}$ .

Modulus of rupture,  $f_{br} = 3PL/2bd^2$

Where,  $f_{br}$  = modulus of rupture in  $N/mm^2$

P = maximum load applied on the specimen

L = length of the span on which specimen is supported

b = width of the specimen

d = depth of the specimen at the point of failure.



**Fig 4.3 Flexural Strength**

#### 4.1.4 Rebound Hammer Test

Procedure for rebound hammer test on concrete structure starts with calibration of the rebound hammer. For this, the rebound hammer is tested against the test anvil made of steel having brielle hardness number of about 5000  $N/mm^2$ . After the rebound hammer is tested for accuracy on the tested anvil, the rebound hammer is held at right angle to the surface of the concrete structure for taking the readings. The test thus can be conducted horizontally on vertical surface and vertical upwards or downwards on horizontal surface. The concrete surface should be smooth, clean and dry. Ant loose particles should be rubbed off from the concrete surface with the grinding wheel or stone, before hammer testing. Rebound hammer test should not be conducted on rough surface as a result of incomplete compaction, loss of grout, spelled or tooled concrete surface.

## V. RESULTS AND DISCUSSIONS

### 5.1 GENERAL

This chapter deals with the results obtained from the various experiments conducted to access mechanical properties. The aim of the study is to determine the compressive strength, flexural strength and split tensile strength. The results of test specimens are presented. The discussion on the results also presented in this chapter.

### 5.2 MECHANICAL PROPERTIES

The mechanical properties of concrete such as compressive strength, flexural strength and split tensile strength are determined from the standard experiments. They are as follows.

#### 5.2.1 Compressive Strength

The compressive strength of replacement of copper slag is arrived. The compressive strength value for replacement of copper slag. Table 5.1 Shows compression test results.

**Table 5.1: Compressive Strength of Cubes with Partial Replacement of Copper Slag**

Curing days	COMPRESSIVE STRENGTH			
	N/mm <sup>2</sup>			
	Mix 1 (0%)	Mix 2 (30%)	Mix 3 (40%)	Mix 4 (50%)
7 days	25.26	26.33	24.76	25.82
14 days	28.68	29.40	28.58	29.17
28 days	37.52	38.47	35.11	36.60

#### 5.2.2 SPLIT TENSILE STRENGTH

The variation of split tensile strength at the age of 28 days with different percentage of copper slag, and fly ash from the test results, it was observed that the maximum split tensile strength was obtained for mix of 15% replacement of fly ash by copper slag. Table 5.2 Split tensile strength test results

**Table 5.2: Split Tensile Strength of Cylinder with Partial Replacement of Copper Slag**

Curing days	Split Tensile Strength			
	N/mm <sup>2</sup>			
	Mix 1 (0%)	Mix 2 (30%)	Mix 3 (40%)	Mix 4 (50%)
7 days	2.20	2.32	2.24	2.57
14 days	2.93	3.10	2.95	3.34
28 days	3.30	3.20	3.46	3.51

### 5.2.2 FLEXURAL STRENGTH

The flexural strength of replacement of copper slag is arrived. Table 5.2 shows flexural strength test results

**Table 5.3: Flexural Strength of beams with Partial Replacement of Copper Slag**

Curing days	FLEXURAL STRENGTH			
	N/mm <sup>2</sup>			
	Mix 1 (0%)	Mix 2 (30%)	Mix 3 (40%)	Mix 4 (50%)
14 days	3.54	3.83	3.70	3.28
28 days	4.48	3.96	3.92	4.73

### 5.4 REBOUND HAMMER TEST FOR BEAM

**Table 5.4 Rebound Hammer Test for Beam for Copper Slag Concrete (30%, 40%, and 50%) In 28 Days**

Sl.No	Rebound Hammer test in 28 days			
	Mix 1 (0%)	Mix 2 (30%)	Mix 3 (40%)	Mix 4 (50%)
1	33	30	31	33
2	30	32	29	32
3	29	30	34	28
4	32	28	32	35
5	33	34	30	30
Avg	32	31	31	32
Compressive strength (N/mm <sup>2</sup> )	30	29	29	30

## VI. CONCLUSION

M30grade concrete is used in this study and tests are conducted for various proportion of copper slag 30%, 40% and 50% in concrete. Based on the experimental investigation, the following conclusions are drawn. The compressive strength occurred above to the targeted strength from 30% in the replacement of copper slag. So, the replacement of copper slag at 50% gave compressive strength to M30 grade and 50% is quite enough to be replaced for compressive strength and also cost efficient too.

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