International Journal For Technological Research In Engineering
Volume 5, Issue 4, December-2017 *ISSN (Online): 2347 - 4718*

AN EXPERIMENTAL INVESTIGATION OF CONCRETE PROPERTIES M30 DUE TO ADDITION OF COPPER SLAG

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Abstract: Many researchers have been currently going to modify and improved the concrete properties by the addition of different types of materials. In this Experiment, we used the byproduct Copper Slag in various percentages as 0%,10%.20%,30%.40%,50% and 60% by the weight of Sand in M30 grade of mix proportion (1:1.60:2.96) with water cement ratio 0.45.This research work mainly consists of addition of copper slag by partially replacement of Sand. For replacement, seven test groups (including control mixture) 0% (control specimen), 10%, 20%, 30%, 40%, 50% and 60% sand with copper slag in each series. Concrete cubes, cylinders, RCC beams and Columns were casted and tested in laboratories. Hence, in this research the Experimental investigations and analysis of results were conducted to study the compressive, tensile and flexural behavior of composite concrete with varying percentage of such copper slag added to it. The concrete mix adopted was M30 with varying percentage of copper slag ranging from 10%, 20%, 30%, 40%, 50% and 60% by weight of Sand. It can be concluded that the Compressive Strength, Flexural Strength and Split Tensile Strength of Copper Slag containing concrete gets increased up to 17 %, 49.15% and 27.35 % with S40% copper slag as compared to plain concrete. Hence replacement of copper slag with 40% of Sand gives economical mix of concrete.

Keywords: Copper Slag, Compressive Strength, Flexural Strength and Split Tensile Strength.

I. INTRODUCTION

The utilization of industrial waste or secondary materials has encouraged the production of cement and concrete in construction field. New by-products and waste materials are being generated by various industries. Dumping or disposal of waste materials causes environmental and health problems. Therefore, recycling of waste materials is a great potential in concrete industry. For many years, by-products such as fly ash, silica fume and slag were considered as waste materials. Concrete prepared with such materials showed improvement in workability and durability compared to normal concrete and has been used in the construction of power, chemical plants and under-water structures. Copper slag is an industrial by-product material produced from the process of manufacturing copper. For every ton of copper production, about 2.2 tones of copper slag is generated. It has been estimated that approximately 24.6 million tons of slag are generated from the world copper industry (Gorai et al 2003). Although copper slag is widely used in the sand blasting industry and in the manufacturing of abrasive tools, the remainder is disposed of without any further reuse or reclamation. Copper slag possesses mechanical and chemical characteristics that qualify the material to be used in concrete as a partial replacement for Portland cement or as a substitute for aggregates. For example, copper slag has a number of favorable mechanical properties for aggregate use such as excellent soundness characteristics, good abrasion resistance and good stability reported by (Gorai et al 2003). Copper slag also exhibits pozzolanic properties since it contains low CaO. further investigations are necessary in order to obtain a comprehensive understanding that would provide an engineering base to allow the use of copper slag in concrete.

II. LITERATURE REVIEW

As we know the properties of concrete gets improved due to the incorporation of Copper Slag. Large no. of papers have being published which tells about the compressive strength, flexural strength and split tensile strength of concrete according to their opinion.

R R Chavan et al [1] reports on an experimental program to investigate the effect of using copper slag as a replacement of fine aggregate on the strength properties. Copper slag is the waste material of matte smelting and refining of copper such that each ton of copper generates approximately 2.5 tons of copper slag. Copper slag is one of the materials that is considered as a waste which could have a promising future in construction Industry as partial or full substitute of aggregates.

T.Ch.Madhavi et al [2] presents the effect of copper slag when included in concrete as a replacement material for sand. It focuses on the effect of copper slag on behaviour of concrete. This paper outlines the properties, preparation and testing and finally the results obtained from experimental investigations using copper slag which is a waste by product produced during the smelting process of manufacture of concrete from its ore. Experimental investigations are carried out by replacing sand with copper slag in content of 10%, 20%, 30%, 40%, 50%, 60% and 100% keeping all other ingredients constant. It is observed that the optimum content of copper slag that can be used as replacement material is 40% beyond which the strength starts decreasing

M. V. Patil et al [3], described the introduction and production of copper slag and its various applications in construction industry. In this paper, the author aimed at the greatest potential applications for using copper slag is in concrete production. This research work by author is concerned with the experimental investigation on strength of concrete and optimum percentage of the partial replacement by replacing fine aggregate via 0%, 10%, 20%, 30%, 40% of

copper slag. In this paper, properties of copper slag concrete and its comparison with the conventional concrete are also mentioned. Future recommendations about copper slag concrete are also included.

Al-Jabri et al [4] investigated 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.

Wei wu et al [5] investigated the mechanical properties of high strength concrete incorporating copper slag as fine aggregate. 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%. A high range water reducing admixture was incorporated to achieve adequate workability.

Al-Jabri et al [6] has investigated the performance of high strength concrete (HSC) made with copper slag as a fine aggregate at constant workability and studied the effect of super plasticizer addition on the properties of HSC made with copper slag. Two series of concrete mixtures were prepared with different proportions of copper slag.

Al-Jabri et al [7] has investigated 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 and durability.

Isa Yuksel and Turhan Bilir et al [8] presented the results of research aimed at studying the possible usage of bottom ash (BA) and granulated blast-furnace slag (GBFS) in production of plain concrete elements. Sufficient number of briquettes, paving blocks and kerbs specimens containing GBFS and BA as fine aggregate replacement were produced in laboratory. Then, a few tests were conducted for investigating durability and mechanical properties of these specimens. Unit weight, compression strength and freeze-thaw tests were conducted for briquette specimens.

Ramazan Demirbog and Rustem Gul et al [9] investigated the use of Blast furnace slag aggregates (BFSA) to produce high-strength concretes (HSC). These concretes were made with total cementitious material content of 460-610 kg/m3. Different water/cement ratios (0.30, 0.35, 0.40, 0.45 and 0.50) were used to carry out 7- and 28-day compressive strength and other properties. Silica fume and super plasticizer were used to improve BFSA concretes. Slump was kept constant throughout this study. Ten percent silica fume was added as a replacement for ordinary Portland cement (OPC) in order to obtain HSC.

Teik-Thye Lim and Chu et al [10] conducted a study on the feasibility of using spent copper slag as fill material in land reclamation. The physical and geotechnical properties of the spent copper slag were first assessed by laboratory tests, including hydraulic conductivity and shear strength tests. The physical and geotechnical properties were compared with those of conventional fill materials such as sands.

Byung Sik Chun et al [11] conducted several laboratory tests and evaluated the applicability of copper slag as a substitute for sand of sand compaction pile method.. From the mechanical property test, the characteristics of the sand and copper slag were compared and analyzed, and from laboratory model test, the strength of composite ground was compared and analyzed by monitoring the stress and ground settlement of clay, sand compaction pile and copper slag compaction pile.

III. MATERIALS USED

Materials required for making Samples essentially consist of cement, fine sand, coarse aggregates and Copper Slag. These materials are described below-

CEMENT: Ordinary Portland cement of 43 grade has been used in this experimental work. OPC 43 grade of ULTRATECH cement has been used after investigate the strength of cement at 28 days as per IS 4031-1988. The various properties of the cement are described in Table No. 1.

Table No. 1. Characteristics Properties of Cement

Sr. No.	Characteristics	Experimental value	Specified value as per IS:8112-1989
1	Consistency of cement (%)	33%	---
2	Specific gravity	2.98	3.15
3	Initial setting time (minutes)	35	>30 As Per IS 4031-1968
4	Final setting time (minutes)	282	<600 As per IS4031-1968
5	Compressive strength (N/mm^2) (i) 3 days (ii) 7 days (iii) 28days	 27.56 40.57 48.96	 >23 >33 >43
6	Soundness (mm)	1.00	10
7	Fineness of Cement	5%	10% As Per IS 269-1976.

FINE AGGREGATES: Locally available river sand passed

through 4.75mm IS sieve has been used in the preparation of Concrete Containing Copper Slag . It confirms to IS 383-1970 which comes under Zone I. The physical Properties of sand like Fineness Modulus, Specific Gravity and water absorption are 3.25, 2.67 and 2.31% respectively.

COARSE AGGREGATES: The Coarse aggregate are obtained from a local quarry has been used. The coarse aggregate with a maximum size 20mm having a specific gravity 2.89. In this experimental work coarse gravel of 20mm and crushed aggregate of 10mm are mixed in 60:40. The physical Properties of coarse aggregates like Fineness Modulus, Specific Gravity are 2.31, 2.89 respectively

COPPER SLAG: - Copper slag is a by-product material produced from the process of manufacturing copper. As the copper settles down in the smelter, it has a higher density, impurities stay in the top layer and then are transported to a water basin with a low temperature for solidification. The end product is a solid, hard material that goes to the crusher for further processing.

Fig 1: Copper slag

WATER: - Water used for mixing and curing was clean and free from injurious amounts of oils, acids, alkalis, salts and sugar, organic substances that may be deleterious to concrete. As per IS 456- 2000 Potable water is generally considered satisfactory for mixing and curing of concrete. Accordingly, potable tap water was used for the preparation of all concrete specimens.

IV. EXPERIMENTAL PROGRAMME

In this section, Concrete Containing Copper Slag has been tested for the compressive strength, flexural strength and split tensile strength.

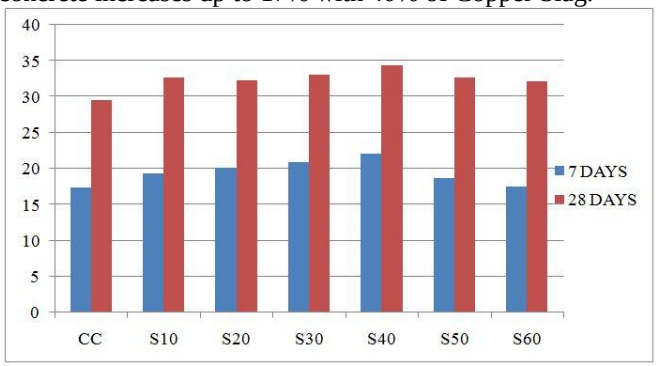
COMPRESSIVE STRENGTH TEST: To examine the compressive strength of GFRC, cube of 150mm×150mm×150mm has been used in this experimental work 30-40 cubes has been casted to determine the compressive strength. firstly cement and sand are mixed uniformly in dry condition . Secondly coarse aggregates are added in this mixture. Now Copper Slag also added according to mix proportion to get the resultant mixture of M30 grade. Required dosage of water was added in the course of mixing. The cube moulds were demoulded after 24 hours then they were placed in water tank containing portable water and were left for curing. After that the specimen are tested at 7 days and 28 days at compression testing machine (CTM) as per IS 516-1959. Compressive strength of concrete mixtures was measured at the ages of 7 and 28 days and shown in Table No. 3. There was an increase in compressive strength of cube concrete specimens produced with Copper Slag.

Fig. 1 CUBE UNDER COMPRESSION TESTING MACHINE (CTM)

Table No. 2: Compressive Strength Results

Mix Designation	7 Days (N/mm²)	28 Days (N/mm²)
CC	17.40	29.55
S(10 %)	19.33	31.62
S(20 %)	20.07	32.25
S(30 %)	20.96	33.11
S(40 %)	22.07	34.44
S(50 %)	18.74	32.74
S(60 %)	17.48	32.22

From the above results, we observe that compressive strength of concrete increases due to incorporation of Copper Slag. From the plot we can say that compressive strength of concrete increases up to 17% with 40% of Copper Slag.



Graph No. 1: VARIATION OF COMPRESSIVE STRENGTH AT DIFFERENT AGE

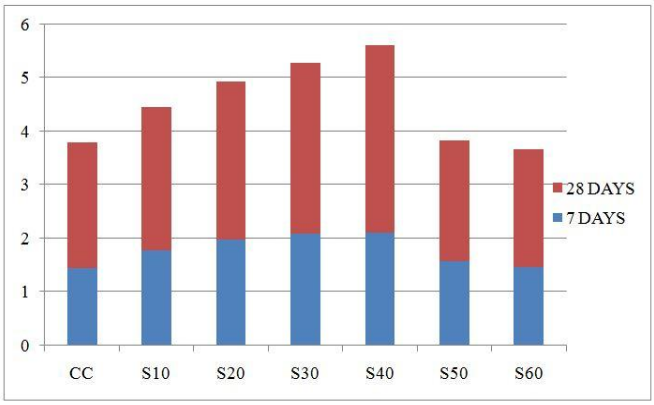
FLEXURAL STRENGTH TEST:- To examine the flexural strength of GFRC, cylinder of size 150mm×150mm×70mm has been used in this experimental work. 30-40 beams has been casted to determine the tensile strength. The beams specimens of different proportions were demoulded after 24 hours and transferred to the curing tank for 28 days . After that, beams were placed to the two point loading machine on which we apply the load manually. Note down the load value at which cracks starts developing on the beam. Table no. 4 shows the values of flexural strength of GFRC beams at different mix proportions. Graph 2 shows the variations of flexural strength at 7 and 28 days.

Fig. 2 TEST SET UP FOR BEAM

TABLE No. 3: Flexural Strength Results

Mix Designation	7 Days (N/mm²)	28 Days (N/mm²)
CC	1.45	2.34
S(10 %)	1.78	2.67
S(20 %)	1.98	2.94
S(30 %)	2.09	3.18
S(40 %)	2.10	3.49
S(50 %)	1.58	2.25
S(60 %)	1.46	2.20

From the above results, we observe that Flexural strength of concrete increases due to incorporation of Copper Slag. From the plot we can say that Flexural strength of concrete increases up to 49.15% with 40% of Copper Slag.



Graph No. 2 VARIATION OF FLEXURAL STRENGTH AT DIFFERENT AGE

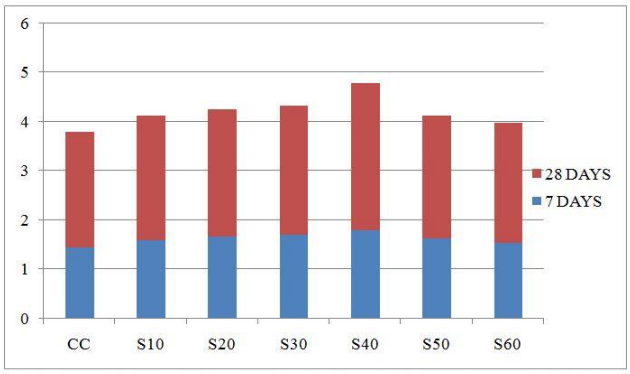
SPLIT TENSILE STRENGTH TEST:- To examine the tensile strength of GFRC, cylinder of size 150mm×300mm has been used in this experimental work . 30-40 cylinders has been casted. The cylinder moulds were demoulded after 24 hours and transferred to curing tank for 28 days. After that cylinders were tested horizontally under compression testing machine (CTM). The results shows that in general, there is an increase in splitting tensile strength of cylinder concrete specimens with the addition of fibres to the concrete at 28 days age.

Fig. 3 CYLINDER UNDER CTM

TABLE No. 4: Split Tensile Strength Results

Mix Designation	7 Days (N/mm²)	28 Days (N/mm²)
CC	1.44	2.34
S(10 %)	1.59	2.53
S(20 %)	1.66	2.58
S(30 %)	1.71	2.60
S(40 %)	1.80	2.98
S(50 %)	1.62	2.49
S(60 %)	1.53	2.44

From the above results, we observe that Split Tensile Strength of concrete increases due to incorporation of Copper Slag. From the plot we can say that Split Tensile strength of concrete increases up to 27.34 % with 40% Copper Slag as compared to plain concrete.



Graph No. 3 VARIATION OF SPLIT TENSILE STRENGTH AT DIFFERENT AGES

V. CONCLUSION

The following conclusions could be drawn from the present investigation.

- The utilization of copper slag in concrete provides additional environmental as well as technical benefits for all related industries. Partial replacement of copper slag in fine aggregate and cement reduces the cost of making concrete.
- The initial and final setting time of copper slag admixed concrete is higher than control concrete.
- Water absorption of copper slag was 0.16% compared with 1.25% for sand. Therefore, the workability of concrete increases significantly with the increase of copper slag content in concrete mixes. This was attributed to the low water

absorption and glassy surface of copper slag.

- It can be concluded that the compressive strength of Copper Slag containing concrete gets increased up to 17 % with S40% copper slag as compared to plain concrete.
- It is observed that the compressive strength of Copper Slag containing concrete gets increased up to S40% copper slag amount after that it starts decreases.
- It is observed that the Flexural strength of Copper Slag containing concrete gets increased up to 49 % as compared to plain concrete.
- It can be concluded that Flexural strength of Copper Slag containing concrete gets increased continuously but after S40% copper slag gets decreased.
- It is also observed that the Split Tensile strength of Copper Slag containing concrete gets increased increases up to 28 % with S40% copper slag as compared to plain concrete.
- Utilization of copper slag as Portland cement replacement in concrete and as a cement raw material has the dual benefit of eliminating the costs of disposal and lowering the cost of the concrete.
- It was observed that, the copper slag replacement for sand is more effective than cement.

5.3 FUTURE SCOPE OF STUDY

- This research was intended to examine the influence of copper slag additions in concrete and RCC elements for M40 mixes. The same word can be extended to higher grades of concrete mixes with varying water/cement ratio.
- Copper slag can be effectively replaced in making bricks, hollow blocks and pavement blocks.
- Since copper slag has higher shear strength value it can be used for soil stabilization.
- Copper slag can be replaced along with fly ash, silica fume and granulated blast furnace slag in concrete and RCC members which can be tested for mechanical performances.

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