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USE OF COPPER SLAG IN CONCRETE AND CEMENT MORTAR AS REPLACEMENT OF SAND

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ABSTRACT

Many researchers have already found it potential to use copper scum as a concrete combination, as a result of copper scum has similar particle size characteristics seemingly to it of sand. Fine grained powder of copper scum is used as a supplementary cementing material to concrete and in cement clinker production. though there are a unit several studies that are reported by investigators from alternative countries on the employment of copper scum in cement concrete, not abundant analysis has been meted out in India regarding the incorporation of copper scum in concrete. This study was performed to come up with specific experimental knowledge on the potential use of copper scum as sand replacement in concrete. This study work chiefly consists of 2 main elements. Concrete was wont to verify numerous mechanical properties. 1st a part of the thesis consists of work sand by copper scum in concrete for determinant strength properties. For sand replacement, seven check teams (including management mixture) were legitimate with replacement of third (control specimen), 20%, 40%, 50%, 60%, eightieth and 100% copper scum with sand in every series. Concrete cubes were solid and tested in laboratories. The optimum proportion of replacement was found by conducting Compressive and split lastingness. Similarly the second a part of the thesis, assessment of corrosion and sturdiness studies were incorporated. Since copper scum contains quite fifty fifth of Fe2O3 content, corrosion and sturdiness factors area unit necessary to seek out . so seven concrete mixtures were legitimate with replacement of third to 100% of copper scum with sand in concrete. Acid and resistance check, inaudible pulse rate (UPV) check, Initial surface absorption check, Capillary suction check were conducted to assess corrosion and sturdiness characteristics. The compressive strength of concrete was determined to be increase by regarding seven-member and split lastingness of concrete by nineteen.3% at four-hundredth replacement of copper scum once twenty eight days of solidifying. There was quite twenty.59% and 12.69% improvement within the compressive and split lastingness of cement mortars with four-hundredth copper scum substitution compared with the management mixture (i.e.100% sand) at twenty eight days of solidifying. the sturdiness and corrosion properties of concrete with 40-50% replacement of copper scum showed higher results compared to manage concrete. it had been found that copper scum within the vary of 40-50% might probably replace sand in concrete mixture and in cement mortars to attain strength and sturdiness needs.

Keywords-copper sum, cement concrete,Fe203 and sturdiness.

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. Over recent decades, intensive research studies have been carried out to explore all possible reuse methods. Construction waste, blast furnace, steel slag, coal fly ash and bottom ash have been accepted in many places as alternative aggregates in embankment, roads, pavements, foundations and building construction, raw materials in the manufacture of ordinary Portland cement pointed out by Teik et. al. (2006).Copper slag is an industrial by-product material produced from the process of manufacturing copper. For every tone of copper production, about 2.2 tonnes 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 manufacture of abrasive tools, the remainder is disposed of without any further reuse or reclamation.

Figure 1. Copper slag sample

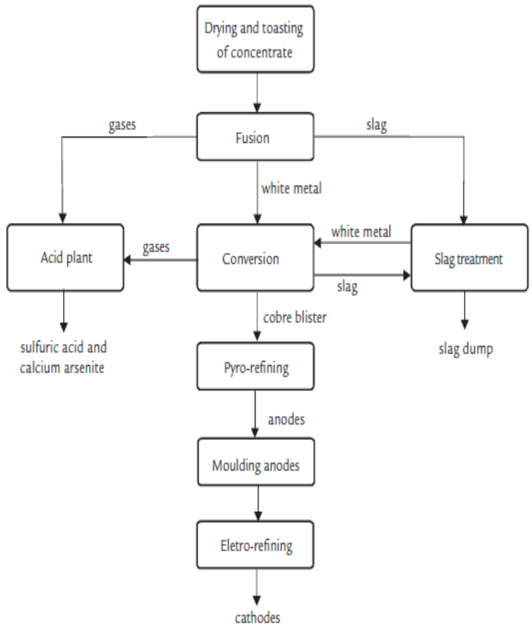

Figure 2: Flowchart represents the Manufacturing processes of Copper slag

A. Advantages of Copper slag

- Reduces the construction cost due to saving in material cost.
- Reduces the environmental impact due to quarrying and aggregate mining.

II. LITERATURE REVIEW

Huang et. al. (2011) carried out the study on copper tailings, the utilization of skarn-type copper tailings to prepare autoclaved aerated concrete (AAC) was studied. The AAC samples were prepared on a laboratory scale with a dry density of 610.2 kg m3 and compressive strength of 4.0 MPa. Compared with the traditional AAC, lime was totally substituted by skarn-type copper tailings and blast furnace slag in order to develop a potential technique of reducing CO2 emission during the AAC production process. The samples of different curing stage were examined by XRD, FESEM as well as 29Si and 27Al NMR analyses. It was found that the main minerals in the AAC product are tobermorite-11 Å, anhydrite, augite, quartz, calcite and dolomite, with small amount of other minerals brought in by the copper tailings. It was also observed that most minerals in the copper tailings participated in the hydration reaction during the procuring process, and the chemical elements in them got into the structure of platy tobermorite in the subsequent autoclaving process.

Nazer et. al. (2012) investigated the effect of using copper slag in cement mortar. Test cubes of mortar were built according to the standard Nch 2260, Of1996 (INN, 1996a) in the form of prismatic bars having, dimensions of 40 x 40 x 160 mm (width, height and length) with mixtures of cement, water and sand. It was observed that the compressive strength of mortar using copper slag is higher than the values achieved in mortars using river sand. It was found that for 3, 7, and 28 day curing times, the mortars with copper slag presented higher compressive strength, 114%, 66% and 44% increase than that of control mix respectively. It was also found that the slag mortars that had curing times of 3, 7, 28 days presented bending resistance superior to 97%, 44% and 35% respectively. It was concluded that copper slag presented greater resistance to compression and bending as compared to mortars manufactured with river sand and also recommend its use in warm climates and/or in situations that demand quick hardening of the mortar.

Shahu et. al. (2013) investigated the influence of important factors such as fly ash content, dolime content, and curing period on the shear strength and stiffness characteristics of copper slag–fly ash–dolime (CFD) mix for its effective utilization in the base course of flexible pavements. Unconfined compression tests are conducted on specimens with different fly ash (10–40%) and dolime (0–20%) contents cured up to 28 days. A mix of 20% fly ash and 80% copper slag stabilized with 15% dolime was found to be the optimum for use in the base course of flexible pavements. Durability tests and unconsolidated untrained triaxial tests are performed on the optimum mix. The strength achieved after 28 days of curing period for the optimum mix was found to be least susceptible to the effect of alternate wet and dry cycles. Empirical relationships are developed to estimate important design parameters such as deviator stress at failure, elastic modulus, and cohesion of the stabilized mix, which can be used to determine dolime and fly ash contents to achieve target strength within a given curing period. Finite-element analyses of a five-layer flexible pavement system are carried out; and the equivalent thickness, service life ratio, and cost-effectiveness of CFD mix in relation to the conventional water-bound macadam (WBM) layer are evaluated.

Ishimaru et. al. (2013) investigated the effect of using copper slag as a replacement of fine aggregate on the strength properties. M25 grade concrete was used and tests were conducted for various proportions of copper slag replacement with sand of 0% to 100% in concrete. The test results indicate that compressive strength of concrete increased by 55% at 40% replacement of fine aggregate by copper slag. It was observed that flexural strength at 28 days is higher than design mix (without replacement) for 20% replacement of fine aggregates by copper slag, the flexural strength of concrete increased by 14%. It was found that compressive strength and flexural strength is increased due to high toughness of copper slag.

III. EXPERIMENTAL STUDY

The objective of the present investigation have been outlines in Chapter-I. To achieve the objectives, an experimental programme was planned to investigate water permeation and strength properties of concrete containing copper slag as replacement of sand. This chapter outlines the experimental programme, planned for the present investigation, in detail. The basic properties of concrete constituent materials, concrete mix details along with method of casting and curing, workability of concrete, details of tests performed on hardened concrete are presented.

A. Experimental Test Programme

- To obtain the physical properties of the concrete constituents i.e. ordinary Portland cement (OPC),Sand, copper slag, coarse aggregate and super plasticizer used.
- Development of various mix combination for concrete.
- Casting and curing.
- Testing of specimens for compressive strength, split tensile strength, UPV test, acid and alkalinity resistance test, Initial

surface absorption test and water permeability test.

- Determining the effects of replacement of sand by copper slag by various percentages on the strengthand durability properties of concrete.

B. Coarse Aggregate

The aggregate size bigger than 4.75 mm, is considered as coarse aggregate. The sand particles should be free from original bed rocks. Coarse aggregate are available in different shapes like rounded, Irregular or partly rounded, Angular, Flaky. It should be free from any organic impurities and the dirt content was negligible. Two types of aggregates with different sizes have been used in the present study. The details of the same are as follows:

I. CA –I aggregate passing 20 mm sieve and retained on 10 mm sieve.
II. CA- II aggregate passing 10 mm sieve and retained on 4.75 mm sieve.

C. Copper slag

Copper slag is a by-product material produced from the process of manufacturing copper. The end product is a solid, hard material that goes to the crusher for further processing. Copper slag used in this work was bought from Sterlite industries (India) ltd, Tuticorin, Tamil Nadu, India. Sieve analysis test was conducted on copper slag and sand in order to determine the particle size distribution and to compare with the gradation requirements for concrete sand and the results were described in Results.

D. Mix-Design

To study the effect of copper slag substitution as a replacement for fine aggregates on the strength of cement mortars, specimens were prepared with different percentages of copper slag (by weight). The percentage of copper slag added were as follows: 0% (for the control mix), 20%, 40%, 50%, 60%, 80% and 100%. Cubes (70.6 mm x 70.6 mm x 70.6mm) were cast for testing compressive strength and split tensile strength of each mixture and were tested after 3, 7, 28, 56 and 90 days of curing. The main purpose for keeping the samples for longer curing periods of 56 and 90 days is to observe any detrimental effect from the use of copper slag as fine aggregate on the compressive strength and split tensile strength of concrete. The quantities of materials are shown in Table 1.

Concrete mixtures with different proportions of copper slag used as a partial or full substitute for fine aggregates were prepared in order to investigate the effect of copper slag substitution on the strength and durability of normal concrete. Seven concrete mixtures were prepared with different proportions of copper slag. The proportions (by weight) of copper slag, added to concrete mixtures were as follows: 0% (for control mix), 20%, 40%, 50%, 60%, 80% and 100%.The control mixture (with 0% copper slag and 100% sand) was designed to have a target 28 days compressive strength of 45 N/mm2, using a water binder ration of 0.45. Batch quantities are shown in Table 2.

TABLE I. Batch Quantities Per Cube For Cement Mortars

Material	**Weight (g)**
Cement	185
Sand	555
Water	74

TABLE II. Values Of Different Materials Used In Control Mix Concrete

Batch quantities (Kg/m3 for concrete mixtures (w/b = 0.45)	
Water	180
Cement	400
Fine aggregate	694
10 mm aggregate	417
20 mm aggregate	624

E. Sample Preparation

Cement mortar sample were compacted in three layers using a vibrating table. After 24 h. Specimens were removed from the moulds and cured in a water tank for later testing at 3, 7, 28, 56 and 90 days. Concrete specimens were prepared. The required amounts of coarse aggregate, fine aggregate, cement, water and copper slag weighted in separate buckets. The materials were mixed in accordance with IS 10262: 2009. The slump of the fresh concrete was determined to ensure that it would be within the desired value. After 24 h, specimens were removed from the moulds and cured in a water tank for 7, 14, 28, 56 and 90 days of curing.

F. Testing Procedure

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

- Compressive strength and split tensile strength was conducted on cement mortar sample at 3, 7, 28, 56 and 90 day of curing.
- 7, 14, 28, 56 and 90 day compressive strength and split tensile strength of concrete
- Acid and alkalinity resistance test was conducted after 56 days of curing in water.
- UPV test, Capillary rise test and surface water absorption test was conducted after
- 56 and 90 days of curing in water.

G. Experimental setup for Concrete Specimens

The size of cylinder used for durability studies (capillary rise test) was 100 mm diameter and 200 mm height. This test was conducted in accordance with IS: 5816-1999. The crude oil was applied along the inner surfaces of the mould for the easy removal of specimens from the mould. Concrete was poured throughout its length and compacted well.

Figure 3: Schematic representation of casted concrete moulds

H. Casting and Curing

The casting of the specimens was done under laboratory conditions using standard equipment as shown in Figure 4. Each batch consisted of two standard cubes for Initial Surface Absorption Test and UPV test, two standard cubes for acid and resistance test, two cylinders of 100 mm diameter and 200 mm depth for Capillary suction tests, 20 standard cubes for determination of 7-days, 14-days, 28- days, 56-days and 90-days compressive strength of each batch.

For each batch of concrete mixed, the quantities of various ingredients i.e. cementitious content, fine aggregate, coarse aggregate, fibres, water, super plasticizer were kept ready in required proportions. Initially the sand and cement were mixed thoroughly to get a uniform mix in dry condition indicated by the uniform colour and no concentration of either material was visible. Then, coarse aggregate were added to this dry mix and turned over twice or thrice in dry state itself in a tilting type rotary drum for one minute. 70% water was added to the mix and remaining 30% water was mixed used for mixing with super-plasticizer to get a uniform mix of required slump. Then mixing was continued for about one minute to get uniform mix.

Figure 4:Concrete Mixture used for Mixture

I. Compressive strength Test

Concrete cubes of size 150mm×150mm×150mm and cement mortar cubes of size 70.6mm×70.6mm×70.6mm were cast with and without copper slag. During casting, the cubes were mechanically vibrated using a table vibrator. After 24 hours, the specimens were demoulded and subjected to curing for 7, 14, 28, 56 and 90 days for concrete cubes and 3, 7, 28, 56 and 90 days in portable water. After curing, the specimens were tested for compressive strength using compression testing machine of 2000KN capacity. The maximum load at failure was taken. The average compressive strength of concrete and mortar specimens was calculated by using the following equation1.

Compressive Strength (N/mm^2)

$$= \frac{Ultimate Compressive Strength (N)}{Area of Cross section of specimen (mm^2)} \quad ....1.$$

J. Split Tensile Strength

Concrete cubes of size 100 mm × 100 mm × 100 mm were cast with incorporating copper slag as partial replacement of sand and cement. During casting, the cubes were mechanically vibrated using a table vibrator. After 24 hours, the specimens were remolded and subjected to curing for 7, 14, 28, 56 and 90 days in portable water. After curing, the specimens were tested for split tensile strength using compression testing machine of 200 tonnes capacity. The ultimate load was taken and the average split tensile strength was calculated using the equation 2.

Split Tensile Strength (N/mm2) = $\frac{0.544P}{A^2}$ -----2.

Figure 5: Compression strength and Split Tensile Strength Testing Machines.

K. Acid and Alkalinity Test

Concrete cubes of size 150 mm x 150 mm x 150 mm were cast and stored in a place at a temperature of 27°C for 24 hours and then the specimens were water cured for 28 days. After 28 days of curing, the specimens were taken out and allowed to dry for one day. Weights of the cubes were taken. For acid attack, 1% of dilute sulphuric acid (H_2SO_4) by volume of the water with pH value of about 2 was used. After that, cubes were immersed in the above said acid water for a period of 28 days.For alkalinity attack, 5% sodium hydroxide (NaOH) by weight of water was added. The concentration of the solution was maintained throughout this period by changing the solution periodically. The specimens were taken out from acid and sulphate solution at 28 days. The surface of the cubes were cleaned, weighed and tested in the compression testing machine.The curing of cubes in acid and alkaline solution was shown in Figure 6.

Figure 6: Cubes kept in acid and alkalinity solution and apparatus for measuring pH of solution (pH meter).

Initial weights of the cubes should be taken before kept in solution. After taking the cubes from the solution after 28 days final weight of the cubes were taken and cubes should be dried for compressive strength testing. The difference between weights and compressive strength should be calculated.

L. Ultrasonic Pulse Velocity Test

The ultrasonic pulse velocity method could be used to establish

- The homogeneity of the concrete
- The presence of cracks, voids and other imperfections, changes in the structure of the concrete which may occur with time.
- The quality of the concrete in relation to standard requirements.
- The quality of one element of concrete in relation to another.
- The values of dynamic elastic modulus of the concrete.

TABLE III: RELATIONSHIP IN BETWEEN UPV & QUALITY OF CONCRETE AS PER IS: 13311:1992

Longitudinal pulse velocity (km/sec)	Approximate compressive strength (N/mm^2)	Quality of concrete
Below 2.0	---	Very poor
2.0 to 3.0	4	Poor
3.0 to 3.5	Up to 10	Fairly good
3.5 to 4.0	Up to 25	Good
4.0 to 4.5	Up to 40	Very good
Above 4.5	>40	Excellent

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Figure 7: Cubes UPV Test Apparatus

M. Capilarity Raise Test

This test method is used to determine the rate of absorption (sorptivity) of water by hydraulic cement concrete by measuring the increase in the mass of a specimen resulting from absorption of water as a function of time when only one surface of the specimen is exposed to water. The exposed surface of the specimen is immersed in water and water ingress of unsaturated concrete dominated by capillary suction during initial contact with water.This test is done as per ASTM standard C 1585–04 Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes.

N. Conditioning

Conditioning of specimens was done by same procedure as adopted for ISAT. After cutting, the specimens were marked and then were kept in oven for drying at (105 ± 5) °C until constant mass was achieved, i.e. not more than 0.1 % weight change over any 24 h drying period. Specimen was then placed in the desiccators to cool down and the temperature in the cabinet was allowed to fall to within 2 °C of that of the room. Silica gel was kept in powdered form in the desiccator to absorb any moisture present in the desiccators. Specimen was kept in the cabinet until required for testing as shown in Figure 8.

Figure 8: Conditioning and drying of samples in dessicator and oven respectively

IV. RESULTS AND DISCUSSIONS

A. Compressive Strength and Split Tensile Strength of Concrete Cubes

Cubes of size 100 x 100 x 100 mm were casted for strength testing. These were cured for 7, 14, 28, 56 and 90 days and tested in Compression testing machine having 200 T capacity. The specimen was placed centrally in testing machine after taking it from curing tank and load was applied continuously, uniformly and without any shock.The load was increased until the specimen fails. The maximum load taken by the specimen was noted. Experiment was repeated for two specimen of same mix. The results of the strength tests conducted on concrete specimens of different mixes cured at different ages are presented and discussed in this section. The compressive strength test results of all the mixes and different curing ages are shown in Table IV.

TABLE IV: CONCRETE COMPRESSIVE STRENGTH RESULTS OF ALL MIXES AT DIFFERENT CURING

Mix Name	Mix Description	Compressive Strength (MPa)				
		7 days	14 Days	28 Days	56 Days	90 Days
M1	100% S	33	38	42	48	53
M2	80% S+20% CS	34	39	43	51	57
M3	60% S+40% CS	36	41	45	53	59
M4	50% S+50% CS	36	40	44	52	56
M5	40% S+60% CS	31	36	38	43	47
M6	20% S+80% CS	29	35	36	41	44
M7	100% CS	28	34	35	40	44

TABLE V: SPLIT TENSILE STRENGTH OF CEMENT MORTARS AT ALL MIXES AT DIFFERENT AGES

Mix Name	Mix Description	Compressive Strength (MPa)				
		3 days	7 Days	28 Days	56 Days	90 Days
M1	100% S	3.25	3.57	3.92	4.21	4.32
M2	80% S+20% CS	3.51	3.88	4.01	4.39	4.45
M3	60% S+40% CS	4.03	4.23	4.49	4.52	4.59
M4	50% S+50% CS	3.93	4.18	4.38	4.49	4.53
M5	40% S+60% CS	3.65	3.88	4.04	4.12	4.38
M6	20% S+80% CS	2.93	3.33	3.69	3.98	4.19
M7	100% CS	2.89	2.99	3.32	3.62	3.92

Figure 9: Concrete specimens subjected to alkalinity attack, compared with normally cured specimens

B. Capillarity Section Test Results

The results of the capillary suction tests conducted on concrete specimens of different mixes cured at different ages are presented and discussed in this section. Typical plots of cumulative water absorption against the square root of time for all concrete mixes at curing time of 56 and 90 days are shown from TableVI. Each set of plots refer to the three specimens tested for each concrete mix. The tests conducted on the three specimens at a particular curing time give identical slopes, particularly during the early part of the test, i.e. the relationship between cumulative water absorption and the square root of time of exposure begins to deviate from linearity after about 6 hours. The variation of sorptivity for different concrete mixes at different curing ages is shown in Table 4.14,

Figure 4.13 shows the variation in average IRA value of concrete mixes at different curing ages. The results clearly show that sorptivity decreases with increase in curing time.

TABLE VI: Variation of Initial Rate of Absorption Values of Various Mixes At Different Curing Ages

Mix No.	Description	Average IRA (mm/Sec1/2)	
		56 days	90 days
1	100% S	0.016	0.014
2	80% S + 20% CS	0.014	0.013
3	60% S + 40% CS	0.012	0.011
4	50% S+ 50% CS	0.01	0.009
5	40% S + 60% CS	0.016	0.013
6	20% S + 80% CS	0.017	0.015
7	100% CS	0.02	0.018

CONCLUSION

The utilisation 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 reduces the cost of making concrete. There is almost 6.67% increase in compressive strength of concrete compared to control mixture (i.e. 100% sand) at 40% copper slag replacement at 28 days of cuirng. Mixture containing 50% copper slag gave higher split tensile strength of concrete, almost 19.3% increase compared to control mixture at 28 days of curing. For cement mortars, all mixtures with different copper slag produces comparable or higher compressive and split tensile strength than the strength of the control mixture. There was more than 20.59% and 12.69% improvement in the compressive and split tensile strength of cement mortars with 40% copper slag substitution in comparison with the control mixture (i.e. 100% sand) at 28 days of curing.From acid resistance test, it was observed that the concrete containing copper slag was found to be low resistant to the H2SO4 solution than the control concrete at high copper slag replacements. From alkalinity resistance test, it can be concluded that control specimens showed higher resistance to alkalinity attack than copper slag replaced specimens.The average pulse velocity of 20%, 40% and 50% (sand replaced specimens) concrete increased to 5.15%, 10.88% and 8.57% than that of control concrete at 56 days of curing. This implies that the quality of copper slag admixed specimens was excellent compared to control specimens. Mixes containing 40-50% copper slag gave the minimum values for both ISAT and IRA values than the control mix (i.e. 100% sand) at 56 and 90 days of curing the volume of permeable voids decreased with the replacement of 40-50% copper slag. From these results, it was found that copper slag in the range of 40-50% could potentially replace sand in concrete mixture and in cement mortars to achieve strength and durability requirements.

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