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Estimating the Strength of Concrete Cube using Copper Slag in the Replacement of Fine Aggregate

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***Abstract*: This paper presents the experimental investigation of properties of concrete using copper slag as replacement material of fine aggregates to increase the hardened concrete properties such as compressive strength, split tensile strength. The present study encouraged the use of industrial by-product or waste copper slag as replacement material of fine aggregates in concrete. Mix proportion has to be done for M25 grade of concrete with water cement ratio 0.50. The fine aggregate is replaced with copper slag in proportions of 0%, 20%, 30%, 40%, 50% and 60% Tests were performed for properties of fresh concrete and hardened concrete. All concrete specimens were cured for 28 days before compression strength test, split tensile strength test, flexural strength test and ultrasonic pulse velocity test. The results indicate that workability and density of concrete increases significantly with the increase of copper slag content in concrete mixes. The results also demonstrated that the highest compressive strength, split tensile strength and flexural strength obtained were 41.53 N/mm2, 3.86 N/mm2 and 5.42 N/mm2 for 40% replacement of fine aggregate by copper slag as compared to control mixture. Therefore, it is recommended that 40% of copper slag can be use as replacement of fine aggregates. Also on the basis of obtained results the empirical relationships between the mechanical properties of concrete were established.**

***Keywords*: Cement, Copper Slag, Fine aggregate, Concrete, Compressive strength, workability and Density**

1. Introduction

A. Copper slag

In the present scenario, as a result of continuous growth in population, rapid industrialization and the accompanying technologies involving waste disposal, the rate of discharge of pollutants into the atmosphere, copper slag is one of the industrial waste which comes out from blast furnace during metal extraction process. Copper slag is produced as a by-product of metallurgical operations in reverberatory furnaces. Originally imported from Japan, copper slag was used as an abrasive material for removing rust and marine deposits from ships through sandblasting. After repetitive recycling and reuse, the copper slag lost its original abrasive property and with no good use thereafter and was disposed in landfills.

Copper slag is totally inert material and its physical properties are similar to natural sand. A laboratory study was carried out in the Institute to research the capability of utilizing copper slag as a fractional substitution of sand in bond concrete.

The utilization of copper slag in bond and cement gives potential natural and in addition monetary advantages for all related enterprises, especially in zones where a lot of copper slag is created.

Due to rapid urbanization, there is a huge requirement of fine aggregate i.e., natural sand for the production of concrete in construction industry, which led to the continuous mining of natural sand from river beds. These results in lot of environmental issues like lowering of water table, erosion of nearby lands, increased pollution due to reduced natural filtration capacity which is detrimental for aqua-culture. Hence Supreme Court imposed certain regulations and restrictions on the mining/ quarrying of sand from river bed locations.

In numerous nations, there is a shortage of normal total that is reasonable for development, though in different nations the utilization of total has expanded as of late, because of increments in the development Industry. Keeping in mind the end goal to decrease consumption of normal total because of development, misleadingly made total and some mechanical waste materials can be utilized as choices.

Thus our project is to utilize the copper slag by the replacement for fine aggregate for maintaining economy and increasing the strength of concrete. By this project we can also solve the problem of disposal of this type of industrial waste. Different types of slag according to the property can be utilized in different purposes.

B. Copper Slag Properties

Copper slag (CS), the smooth material, created amid matte purifying and copper transformation was already viewed as waste and arranged as landfill. It has been evaluated that for each ton of copper creation around 2.2-3 tons of slag are produced.

Copper slag, a copper creation buildup, appears in its compound organization high substance of aluminum, silica and iron oxides, like that of concrete. Furthermore, its hardness and degree appears to demonstrate its reasonableness for use as option total for applications in development items. Total is the fundamental constituent of cement, involving over 70% of the solid lattice. Slag containing < 0.8% copper are either disposed of as waste or sold efficiently.

In this paper the results of an experimental study on the physical, chemical, mineralogical characterization and environmental classification of copper slag is presented. Copper slag is similar to sand in grading and its, non-absorptive, hard non-reactive properties make it an ideal fine filler material for concrete after it is suitably washed to remove all impurities in that. Even though Waste Copper Slag produces no dust, has low crystalline silica (less than 0.1%) making it an environmentally friendly product, its usage was not explored to its full potential due to the conservative nature of the industry.

Slag was used in Pavement Quality Concrete as well as in Dry Lean Concrete mixes and its influence on workability, compressive strength, and flexural strength was determined.

C. Necessity of present study

The demand for natural sand is quite high in developing countries since the available sand is not able to meet the demands of construction sector, because natural sand takes millions of years to form and it is not replenish able. Due to continuous dragging of the sand from. River beds reduce the water head, leads to less percolation of rain water in to the ground. This leads to lower ground water level, which results in scarcity of drinking water.

Hence there is an urgent need to identify a suitable substitute for natural sand, which should be eco-friendly and inexpensive. On the other hand, large quantities of slag produced as a by-product of metallurgical operations, resulting in environmental concerns with its disposal.

Hence, there is an increased need to explore the possibility of utilization of Industrial waste materials in making concrete. This will lead to sustainable concrete design and greener environment.

D. Replacement of fine aggregate with copper slag

The effect of the partial replacement of sand by slag on mortar and concrete properties is investigated. Two different sands and four different volume contents of copper slag 20, 40, 60 and 80% were used in mortar mixtures. Firstly the plain concrete cubes will be casted without any replacement of copper slag of ratio 1:1:2 [cement: fine aggregate: coarse aggregate (10mm and 20mm)] of size (15x15x15) cm. After that cubes with different percentage of copper slag replacement will be casted. Concrete mixes incorporating copper slag instead of fine aggregate, with different cement contents, are also produced and characterized.

The comparison to control mixtures indicates that cooper slag might be suitable for mortar and concrete. Copper slag residues are also used for the production of concrete blocks. After 7th, 14th and 28th days the compressive strength will be determined. The comparison between the compressive strength of both the normal and of replaced percentage of copper slag cubes will be done.

2. Literature review

Washington Almeida Mouraet al. (4th Brazilian MRS Meeting), 2007. This paper shows the consequences of a review on the utilization of Copper Slag as Puzzalonic Supplementary Cementing material for use in cement. At first the substance and mineralogical attributes of the Copper Slag were resolved. After this, solid clumps were made with copper slag increases of 20% (in respect to the concrete weight) and set properties were researched, i.e., particular gravity, compressive quality, part ductile, assimilation and retention rate by narrow suction and carbonation. The outcomes brought up that there is a potential for the utilization of copper slag as a supplementary establishing material to solid generation. The solid clumps with copper slag expansion displayed more noteworthy mechanical and strength execution. The fallowing conclusions were drawn from this review. The expansion of copper slag to solid outcomes in an increment on the solid's hub compressive and part elastic qualities. It was watched that a decline in the assimilation rate by narrow suction, ingestion and carbonation profundity in the copper slag cement and its toughness additionally made strides.

Hwang C.L. and Laiw J.S., detailed that the measure of seeping of mortar made with Copper slag is relatively not as much as that utilizing characteristic sand. They assessed the Compressive Strength advancement of mortars and cement containing fine Copper slag total with various water-bond proportions. The outcomes demonstrated that the mortars containing the a lot of Copper slag sand has bring down early Strengths at water-bond proportion of 0.48. The Strengths of Concrete with 20-80 % substitution of Copper slag was observed to be higher than that of Control solid examples (with 0% of C.S.).

Al-Jabri KS et al. detailed that the measure of seeping of mortar made with Copper slag is relatively not as much as that utilizing characteristic sand. They assessed the Compressive Strength advancement of mortars and cement containing fine Copper slag total with various water-bond proportions. The outcomes demonstrated that the mortars containing the a lot of Copper slag sand has bring down early Strengths at water-bond proportion of 0.48. The Strengths of Concrete with 20-80 % substitution of Copper slag was observed to be higher than that of Control solid examples (with 0% of C.S.).

D.Brindha et al. announced the Compressive Strength and the Split Tensile Strength test have demonstrated that the Strength of Concrete increments regarding the % of Slag included by weight of fine total up to 40% of increases and 15% of bond. Water ingestion of Concrete examples (with up to 40% of Copper slag) is 22% lower than the controlled examples and lesser porousness of Slag admixture Concrete. In addition, the expansion of Copper slag for the substitution of common sand demonstrates higher resistance against Sulfate assault yet somewhat low imperviousness to the Sulfuric (corrosive resistance test).

R. R. Chavan& D.B. kulkarni (2013) led test examinations to concentrate the impact of utilizing copper slag as are situation of fine total on the quality properties and presumed that Maximum Compressive quality expanded by 55% at 40% substitution of fine total by copper slag and flexural quality expanded by 14% for 40% substitution.

Khalifa et al, reported that the use of Copper slag as sand substitution improves strength and durability characteristics of High Strength Concrete at same workability and produces Concrete that meets Strength and durability Design requirements.

3. Data collection

A. General

The program was designed to describe the selection of materials, types of tests to be conducted to evaluate their properties, to prepare Design mix, to furnish casting, curing and testing procedures adopted in order to compare the mechanical properties of Concrete i.e., Compressive Strength, Splitting Tensile Strength and Flexural Strength with different percentages of Copper slag used as fine aggregate, in blending with natural sand.

B. Selection of materials

1) Cement

The Cement selected for this experimental work is the Ordinary Portland Cement of 53- Grade (Ultra-Tech Brand) conforming to IS: 12269-1987. This brand of cement is most widely used in the construction industry in India. The Physical properties of cement i.e. initial and final setting times, Specific gravity, fineness, consistency has to be checked, before conducting the Mix-Design.

2) Coarse aggregate

In the present study, locally available Coarse aggregate (Robo-Metal) of size 20mm was used. Its Specific gravity, Sieve analysis and Fineness Modulus have to be checked.

3) Fine Aggregate – Natural Sand

Locally available natural sand was used. Its Specific gravity, Sieve analysis and Fineness Modulus need to be checked. The Sieve analysis has to be conducted to classify the sand belonging to which Zone (I to IV), as per IS 383:1970. As sand grading becomes progressively finer, the grading changes from Zone-I to IV.

4) Fine Aggregate – Copper Slag

The Chemical analysis of Copper Slag has to be conducted, to check its Chemical composition. Simultaneously the tests to determine the Physical properties of Copper Slag i.e. Specific gravity, Sieve analysis and Fineness modulus has to be conducted.

C. Present status of copper slag utilization

Aggregate is the primary constituent of cement, possessing over 70% of the solid network. In numerous nations, there is a shortage of common total that is reasonable for development, though in different nations the utilization of total has expanded as of late, because of increments in the development business. Keeping in mind the end goal to diminish consumption of characteristic total because of development, misleadingly made total and some modern waste materials can be utilized as choices. Copper slag (CS), the shiny material, created amid matte refining and copper transformation was already viewed as waste and arranged as landfill. It has been estimated that for every ton of copper production about 2.2-3 tons of slag are generated.

Slag containing < 0.8% copper are either discarded as waste or sold cheaply. The copper slag, the byproduct of the melting plant of Lac, copper slag can be used successfully as Portland cement substitute in the cement industry, sand substitute in concrete plant and in different ways.

The treated spent copper slag can be recycled and put to good use as sand replacement in concrete. For structural usage, the use of copper slag as partial replacement of sand in concrete is allowed for up to 10% by mass.

D. Observation and analysis

Chemical analysis results (Table 1) show that high review limestone (LS-HG) and normal review limestone contain 49.60% and 45.00% of CaO individually, 3.31% and 12.57% of SiO_2 and 3.25% and 1.98% of MgO. Optical minute examination showed the nearness of calcite as a noteworthy mineral with vein lets of quartz. These lime stones are fine grained and a couple shows considerations of clayey matter. These outcomes show that both lime stones can be viewed as reasonable for the fabricate of OPC. While planning the crude blends, endeavors were made to keep the level of use of copper slag to the greatest conceivable degree. But since of nearness of the high Fe2O3 content (68.36%), its extent in the crude blends couldn't be expanded past 3.0%.

The free lime content in all the clinker samples was found to be less than 0.20% at 1350°C. However, to eliminate the possibility of free silica and also to provide a safety margin, 1400°C was considered more appropriate temperatures for clinkerisation with a retention time of 20 minutes. Further bulk clinker (~10kg) was prepared from raw mix RM-3 and characterised for chemical and mineralogical composition. There was no free lime in the clinker sample. SiO_2 and CaO contents were found to be 21.54 and 63.45%. The phase composition calculated by Bogues formulae indicates that the quality of clinker is good and is capable of yielding good quality cement. quality cement.

E. Observation and Analysis

Chemical analysis of granulated impact heater and copper slag are given in Table 1. The outcomes demonstrate that granulated impact heater slag fits in with every one of the prerequisites of Indian Standard Specification IS: 12089-1987 for the make of PSC dissimilar to copper slag. This is because of the nearness of higher insoluble deposit (28.56%). So also, the glass content in granulated impact heater slag was observed to be 96% as against 1.5%. It additionally does not adjust to the necessity of module esteem laid in the standard. Mineral structures of granulated impact heater and copper slag were dictated by X-beam diffraction investigation and the outcomes demonstrated the nearness of basically nebulous material in both the slag tests. PSC mixes were readied utilizing OPC test (OPC-Control) gathered from a noteworthy concrete plant and both the slag independently in the scope of 25 to 40%. The aftereffects of their physical execution are presented.

4. Methodology

A. Site

I have selected the Vaishnavi Constructions near Zahirabad at raikod site for casting and checking work of concrete. They have allowed us to work on their laboratory. They have provided better guidance and helped us in casting cubes. The concreting materials, cube moulds and strength testing machines were available at the site. Only copper slag was required to bring from outside. That we have bought from Prakash Steel India Pvt. Ltd.

B. General

For the strength study of copper slag we have to cast concrete cubes containing different percentage of copper slag. For the cost comparison and strength comparison of copper slag concrete we have to cast concrete containing zero percentage of copper slag that means the plain concrete i.e. concrete of fine aggregate.

We are going to prepare concrete of grade M25. For this the ratio used of cement, fine aggregate and coarse aggregate is 1:1:2.1(Cement): 1(fine aggregate): 2(coarse aggregate) this ratio was mixed completely with water of 500 ml and then concrete cubes were casted.

C. Mixing of Concrete

The mix proportions are finalized for each mix as per the Design-Mix. Then the constituents of Concrete Viz., Cement, Natural Sand, Copper Slag, Coarse Aggregate (20mm) and water were weighed separately. The materials were mixed in a rotating pan mixer in accordance with ASTM C192-98.

First Coarse aggregate, fine aggregate (both natural sand and Copper slag) and Cement were mixed dry in pan mixer for 2 to3 minutes, until a homogeneous mix was obtained.

Then water was added in two stages as below:

1. 50% of total water added to the dry mix of Concrete in first stage and mixing continued for 2 minutes.
2. Remaining 50% of water added to the above mix and mixing continued for another 3 minutes till the homogeneous mix is achieved.

D. Properties of fresh concrete

The behavior of Fresh Concrete from mixing up to compaction depends on the property called “Workability of Concrete”. A workable mix should not segregate. The Workability of Concrete was measured by the test called “Slump Test”. It is the most commonly used method of measuring consistency of concrete. Information on workability and quality of concrete can be obtained by observing the manner in which concrete slumps.

5. Results

A. Compressive strength test

Compressive Strength describes the behavior of the material when it is subjected to a Compressive load at a relatively low and uniform rate of loading until the failure occurs. Compressive Strength of Concrete is a primary physical property and one of the most frequently used in design calculations for Bridges, Buildings and other Structures. This Compressive Strength is expressed as load per unit area.

The specimen’s i.e. cubes (of size 150 mm x 150 mm X 150 mm) were tested in accordance with IS 516:1969. The testing was conducted on a Compressive Testing Machine of capacity 3000 KN. The CTM has the facility to control the rate of loading, with the control valve.

Testing procedure

1. The test specimens are taken out from the curing tank, on the prescribed date of testing as per test procedure.
2. The specimens are wiped and cleaned. Then allowed to dry for 2 to 3 hours.
3. The self-weights of the individual cubes are recorded before conducting the test.
4. Then the specimen is placed in between the plates of the CTM and is tightly fixed, so that the specimen should not move (at the time of applying load).
5. After this, the load was applied on the cube by pressing the on button. The load is increased gradually until the cube fails to take further load. At the point of failure, the Maximum load applied is recorded.
6. Compressive Strength of Cube = Max.Load applied/C.S. Area of Cube.

Table 1
% Replacement of sand with copper slag

% Replacement of Sand with Copper Slag	M-25 Grade Concrete Mix		
	7-Days	28-Days	90-Days
0%	27.44	41.16	51.63
10%	27.96	43.23	52.39
20%	31.49	45.67	53.61
40%	31.91	46.91	55.17
50%	32.63	47.41	55.51
60%	29.26	45.85	50.46

B. Split tensile strength test

The splitting test is well known indirect test used for determining the tensile strength of concrete. This is also sometimes referred as “Brazilian Test”.

The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a Compression Testing Machine and the load is applied until failure of the cylinder occurs, along the vertical diameter.

Test Procedure

Concrete cylinder specimens (size 150 mm dia. and 300 mm long) are taken out from the curing tank, then properly wiped and cleaned.

1. The same testing machine used for the Compression test is employed for this test.
2. The cylindrical specimens are placed horizontally between the loading surfaces of CTM. Fig. shows the testing specimen and the stress pattern in the cylinder respectively.
3. The loading condition produces a high compressive stress immediately below the two generators to which the load is applied. But the larger portion corresponding to depth is subjected to a uniform tensile stress acting horizontally.
4. The Compressive load is applied until failure of the cylinder takes place.

$$\text{Max. Tensile Strength of Cylinder} = 2P/\pi DL$$

Where,

P - Max. Compressive Strength applied on the Cylinder
L - Length of the Cylinder
D - Diameter of the Cylinder

Table 2
% Replacement of sand with copper slag

% Replacement of Sand with Copper Slag	M-25 Grade Concrete Mix		
	7-Days	28-Days	90-Days
0%	2.236	2.924	3.290
10%	2.546	3.025	3.303
20%	2.645	3.123	3.340
40%	2.685	3.130	3.350
50%	1.758	2.982	3.670
60%	1.798	2.992	3.675

6. Conclusion

From the above result it can be concluded that we are going to use copper slag as an alternative of fine aggregate the cost of concrete production will be reduced and strength of 60% replaced copper slag concrete will be increased to twice of plain concrete strength.

Based on the experimental investigations carried out, the following conclusions were drawn:

1. The behavior of Copper Slag seems to be similar to River Sand, for its use as fine aggregate (partially or in blending) in Concrete mixes.
2. Addition of Copper Slag (having higher Density) in Concrete increases the density, thereby the self-weight of Concrete, (by about 4.5% for 50% replacement).
3. The results showed that the workability of Concrete increased substantially with increase of Copper Slag content in the concrete mixture due to the low water absorption, coarser (in nature than sand) and glassy surface of Copper slag, thereby the Strength properties also improved.
4. The Compressive Strength of Concrete is comparable to the control mix up to 40% of Copper Slag substitution, but they decrease with a further increase in Copper Slag contents (due to the increase of free water content in the mix).
5. The early Compressive Strength of Concrete was not adversely affected by Copper Slag addition up to the proportion of 40%.
6. Compressive Strength and Flexural Strength of Copper Slag admixture Concrete, increased due to high toughness of Copper Slag.
7. Replacement of Copper Slag as fine aggregate in concrete mixes reduces the cost of concrete production.

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