PERFORMANCE OF CONCRETE MADE WITH THE COPPER SLAG AS A PARTIAL REPLACEMENT OF FINE AGGREGATE

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Abstract: *Copper slag, a slag from metal smelting process, is efficiently used as a partial replacement for sand in conventional concrete which is highly efficient in increasing the strength without affecting it's properties in fresh and hardened state. In this study M25 grade of concrete is taken for partial replacement of sand with copper slag. Cubes and cylinders are casted and cured to conduct compressive strength and split tensile strength test on 7 days and 28 days. Slump of concrete mix with different proportions are also measured and recorded. Obtained results on different parameters like strength, workability were compared with those of control concrete made with ordinary Portland cement, sand and coarse aggregate.*

Keywords: Concrete, copper slag, split tensile strength, workability and compressive strength.

1. INTRODUCTION

Now a days there is lack of River sand and also increment of lots of restrictions on river sand mining and its transportation. For that it becomes necessary to find the alternative for river sand. It is beneficial to find the by-product so that its cost is comparatively less and also it can be usable. For that the Copper Slag is one of the best alternatives. Copper slag is an industrial byproduct obtained during matte smelting and refining of copper. By using copper slag in concrete we can reduce environmental pollution as well as we can reduce the cost of concrete also. Copper slag can possesses the physical, chemical and mechanical properties that can be used in concrete as a partial replacement for fine aggregates. Copper slag is one of the materials that can be considered as a waste material which could have a promising future in construction industry as a partial or full substitute of any two either cement or aggregates. It is an industrial by-product material produced during the copper smelting and refining process of manufacturing of copper which can be used for a surprising number of applications in the construction of buildings and in many other industrial fields. This material represents a popular alternative to the sand as a blasting medium in industrial cleaning. Nowadays, using blasting or high- pressure spraying techniques, companies are using copper slag to clean large smelting equipment or furnaces. Materials like copper slag can be used as one which can reduce the cost of construction.

Approximately 24.6 million tons of slag is generated throughout the worldwide.

Objectives

The objective of this work is to investigate the properties of concrete with the partial replacement of fine aggregate by copper slag, and also to scrutinize the following:

- To inspect the performance of concrete made with the copper slag as a replacement of fine aggregate.
- To evaluate the workability, compressive and split tensile strength of concrete by using copper slag in concrete specimens.
- To find the optimum proportion of copper slag that can be gained maximum strength and that proportion will be used as a partial replacement substitute material for fine aggregate in concrete.
- To debrief the physical properties by use of copper slag for fine aggregate in concrete samples.
- To inspect the performance of concrete made with the copper slag as a replacement of fine aggregate.

2. MATERIALS USED

Materials needed for Reinforcement cement concrete are cement, fine aggregate, coarse aggregate, copper slag and water.

2.1 Cement: Cement is a binder, a substance that sets and hardens and bind other materials together. The cement used in this experimental work is OPC43.

Table -1: Properties of cement

Sl.No.	Property	IS recommendation
01.	**Specific Gravity**	**3.14**
02.	**Consistency**	**51**
03.	**Initial Setting Time**	**30 minutes**
04.	**Final Setting Time**	**10 ours**

2.2 Sand: Sand is a naturally occurring granular material composed of the finely divided rock and mineral particles. It is defined by size, being finer than gravel and coarser than the silt.

2.3 Copper Slag (CS): Copper slag is an industrial by-product material produced from the process of manufacturing of copper having almost similar physical, mechanical &chemical properties of Sand can be considered as an alternative to the river sand.
Copper slag is a byproduct of operation of reverberatory furnaces, these furnaces used for the manufacturing of the copper. A large amount of the concentrate, up to about 300 tons, may be placed in these furnaces at one time. Impurities form a less dense liquid that floats on top of the copper melt. These impurities include iron, silica, and lime, and form the slag. The slag is skimmed off from the top, while the melted material, which has up to 50 percent copper, is called matte. The copper matte goes through the converter to blow forced air into it. The air forces the silica back into the copper matte to collect the remaining impurities and make more slag. The slag is skimmed off again and air cooled. The slag is subjected to a process of staged crushing using jaw and impact crushers and screened to achieve a angular and uniform particle shape.

Benefits of Copper Slag

- It provides good cohesive pumpable mix at low water cement ratio & moderate cement contents.
- It imparts extreme fluidity to the concrete, which facilitates rapid placement of concrete
- It also helps in controlled & predictable retardation of setting with improved slump retention.
- The copper slag uses is 3 to 4 times economical when compared to river sand.
- Some of the mosaic companies, used copper slag to replace sand.
- It is useful in production of self-compacting concrete.
- It can be applied in complicated formwork or with congested reinforcement.
- Achievement of good compaction without any excessive vibration.
- Reduces permeability, segregation and bleeding.
- Helps in increasing compressive and flexural strength.

2.4 Coarse Aggregate: Aggregates are the most mined materials throughout the world. Aggregates are the component of composite materials such as concrete and asphalt concrete; the aggregate serves as reinforcement to add strength to the overall composite material.

Table -2: Properties of FA, CA, CS

S.No	Properties	FA	CA	CS
01.	Specific Gravity	2.642	2.701	3.679
02.	Fineness Modulus	3.237	7.416	3.423

2.5 Water: Water is an important ingredient of concrete as it actively participates in the chemical reaction with the cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to become very important.

3. METHODOLGY

M25 grade of concrete is designed in accordance with the guidelines of IS code 10262:2009 with replacement of fine aggregate by copper slag. Copper slag is added at varying percentages of 0%, 20%, 40%, 60% and 80% by replacing fine aggregate. The compressive strength samples are casted and cured in water for 7 days and 28 days. The split tensile strength specimens are casted and cured in water for 28 days. After curing period is over, they are tested for their respective strengths.

3.1 Mix Design: Mix design carried out for M25 grade of concrete by IS 10262:2009. The replacement of sand by Copper Slag (CS) was 20% to 80% at increment of 20% each.

Table-3: Different combinations of mixes

Mix Designation	Mix details (Sand + Copper Slag)
S-1	100% Sand+0%CS
S-2	80% Sand + 20%CS
S-3	60% Sand +40%CS
S-4	40% Sand + 60%CS
S-5	20% Sand +80%CS

3.2 Tests Conducted

A. Slump Cone Test

The Slump Cone apparatus for conducting the slump test essentially consists of a metallic mould in the form of a frustum of a cone having the internal dimensions such as given: Bottom diameter: 20 cm, Top diameter: 10 cm, Height: 30 cm and also the thickness of the metallic sheet for the mould should not be thinner than 1.6 mm.

B. Compressive Strength Test

One of the most important properties of the concrete is the measurement of its ability to withstand compressive loads. This load withstand capacity is referred to as a compressive strength and is expressed as load per unit area. One method for determining the compressive strength of concrete is to apply a load at a constant rate on a cube (having dimensions 150×150×150 mm), until the sample fails. The compression tests performed in this were completed in accordance with IS code 516 "Methods of Tests for Strength of Concrete". For this study samples were tested for compression testing at 7 and 28 days of curing.

C. Split Tensile Strength:

To find the split tensile strength of concrete, cylindrical samples (150mm dia x 300mm depth) were cast with 0 %, 20%, 40%, 60% and 80% replacement of fine aggregate by granulated copper slag under standard conditions. Load is applied gradually at a uniform rate to the cylinder specimen without causing any sudden failure until the dial gauge reading recedes in the reverse direction.

4. RESULTS AND DISCUSSION

4.1 Tables:

Table-4: Workability of concrete with partial replacement of sand by Copper Slag

Mix Designation	Copper slag (%)	Slump Value (mm)
S-1	0	62
S-2	20	57
S-3	40	55
S-4	60	53
S-5	80	50

Table-5: Cube Compressive Strength of concrete with partial replacement of sand by Copper Slag at 7 days curing period

Mix Designation	Replacement of fine aggregate by copper slag (%)	7th day Compressive strength (N/mm²)
S-1	0	26.07
S-2	20	29.8
S-3	40	32.02
S-4	60	27.53
S-5	80	25.71

Table-6: Cube Compressive Strength of concrete with partial replacement of sand by Copper Slag at 28 days curing period

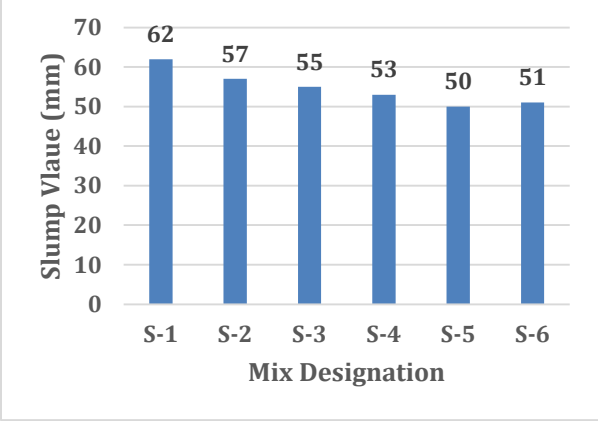
Mix Designation	Replacement of fine aggregate by copper slag (%)	28th day Compressive strength (N/mm²)
S-1	0	27.43
S-2	20	30.07
S-3	40	34.51
S-4	60	29.42
S-5	80	27.62

Table-7: Split tensile strength of concrete with partial replacement of sand by Copper Slag

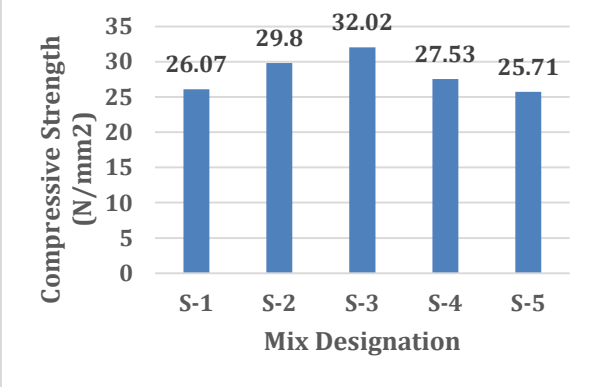
Mix Designation	Replacement of fine Aggregate by copper slag (%)	Split tensile strength (N/mm^2)
S-1	0	2.61
S-2	20	2.85
S-3	40	2.97
S-4	60	2.17
S-5	80	1.83

4.2 Graphs:

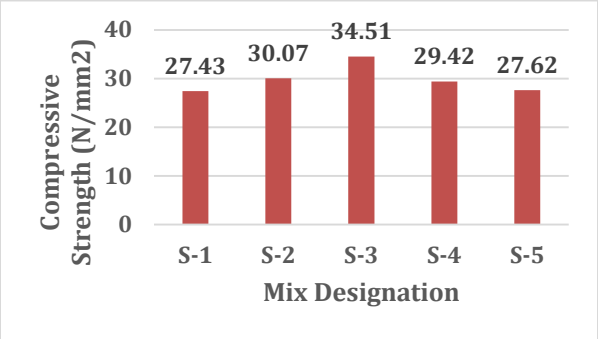
Graph-1: Workability of Concrete with % of Copper Slag



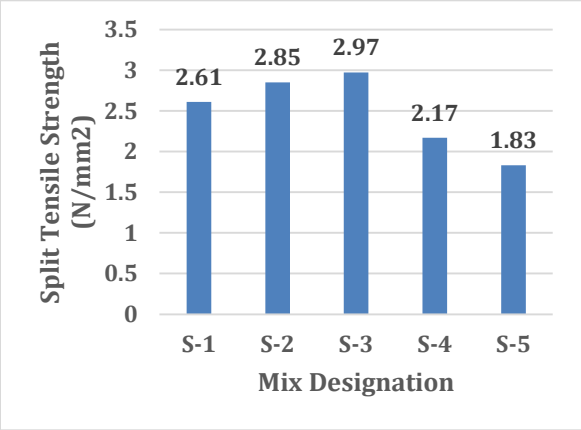
Graph-2: Cube Compressive Strength of Concrete with % of Copper Slag at 7days curing period



Graph-3: Cube Compressive Strength of Concrete with % of Copper Slag at 28 days curing period



Graph-4: Split Tensile Strength of Concrete with % of Copper Slag at 28 days curing period



4.3 Discussion:

A. Influence of Copper Slag percentages on workability of concrete

From the Table-4 and graph-1, the workability of the concrete decreases as the percentage of the copper slag is increases.

Without adding copper slag to the concrete the workability is 62 mm, when the 80 % copper slag is added the slump value is 50 mm, which is a decrease in workability of 19.35% was observed for 80% copper replacement.

B. Influence of Copper Slag percentages on Compressive strength of concrete

From the Table 5 & 6, graph 2 & 3 were shown variation of compressive strength in Conventional concrete with replace of copper slag different dosages 0%, 20%, 40%,60% and 80% are added. From the tables and figures the following observations are made:

i. At 7 days curing:

The compressive strength (Table-5, graph 2) of the mix M25 i.e. without mixing of Copper Slag is 26.07 N/mm^2 for 7 days. In the present investigation the Copper Slag has been used as partial replacement to sand up to a maximum of 80%. When Copper Slag is used as replacement in different percentages the strength firstly increased then decreased.

For e.g., with 20% replacement of sand by Copper Slag, the compressive strength at 7 days is 29.80 N/mm^2 and there is an increase of compression strength by 14.30 % in comparison to the concrete when sand is used as a fine aggregate. While considering 40% replacement, the compressive strength is 32.02 N/mm^2 there is an increase in compressive strength by 7.44%. With 60% replacement, the compressive strength at 7 days curing period is 27.53 N/mm^2, and the decrease in compressive strength by 14.02%. With 80% replacement, the compressive strength is 25.71 N/mm^2, and the decrease in compressive strength by 6.61%. From this strength it is clear that there is no advantage in using Copper Slag beyond 40%. Hence, 40% Copper Slag can be taken as the optimum dosage, which can be mixed as a partial replacement to sand for giving maximum possible compressive strength at any stage.

All strengths of copper slag based concrete specimens are comparable with Conventional concrete specimens. Among all copper slag dosages 40% of copper slag concrete given more strength can be considered as optimum dosage for the concrete.

ii. At 28 days curing

The compressive strength (Table-6, graph 3) of the mix M25 i.e. without mixing of Metakaolin is 27.43 N/mm^2 for 28 days.

Moreover, with 20% replacement of sand by Copper Slag, the compressive strength at 28 days is 30.07 N/mm^2 and there is an increase of compression strength by 9.62 %. While considering 40% replacement, the compressive strength is 34.51 N/mm^2 there is an increase in compressive strength by 14.76%. With 60% replacement, the compressive strength at 28 days curing period is 29.42 N/mm^2, and the decrease in compressive strength by 14.74%. With 80% replacement, the compressive strength is 27.62 N/mm^2, and the decrease in compressive strength by 6.11%.
All strengths of copper slag based concrete specimens are comparable with Conventional concrete specimens. Strength increases with increase in dosage of copper slag upto 40%.

C. Influence of Copper Slag percentages on Split Tensile strength of concrete

By observing above graphs the split tensile strength is going on increasing up to 40%. Normally the concrete is weak in tension but the replacement of copper slag was giving better results than the use of sand.

In the case of split tensile strength (Table-7 and graph 4) the 28 days value without Copper Slag is 2.61N/mm^2. When 20% replacement is used the split tensile strength is 2.85 N/mm^2. There is increase in strength by 9.19%. The split tensile strength at 28 days with 40% replacement is 2.97 N/mm^2 showing an increase of strength by 4.21%. With 60% replacement the tensile strength for 28 days is 2.17 N/mm^2. There is decrease in strength by about 2.69% only. Hence, it is advisable to use 40% as- replacement. Hence the optimum percentage of Copper Slag is again 40% even in the case of split tensile strength.

CONCLUSIONS

After interpretation of results and discussions the following conclusions are arrived.

1. By adding different % of copper slag in conventional concrete it was observed that the slump value decrease as the percentage of the copper slag is increased.

2. By adding different % of copper slag in conventional concrete we observed that compressive strength increases upto a percentage of copper slag of 40%. After adding more than 40% copper slag to the concrete the compressive strength of the concrete goes to decrease.

3.. The split tensile strength of concrete increased with increased copper slag content in concrete upto a certain proportion after that the split tensile strength decreases.

From all the above tests considering finally we observed that optimum dosage of copper slag is 40%.

Hence from this investigation it can be concluded that copper slag is an alternative material to natural sand as fine aggregate in concrete.

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