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STUDY ON CONCRETE USING COPPER SLAG AS REPLACEMENT MATERIAL OF FINE AGGREGATE

Prof. P. S. Kumbhare[1], Ms. Apurva S. Zende[2], Ms. Aishwarya B. Gotekar[3], Mr. Tejas N.Cute[4].
[1]*Asst.Professor, Department of Civil Engineering, J.D.I.E.T., Maharashtra, India,* ***pallu15kumbhare@rediffmail.com***
[2]*Student, Department of Civil Engineering, J.D.I.E.T., Maharashtra, India,* ***apurva26@gmail.com***
[3]*Student, Department of Civil Engineering, J.D.I.E.T., Maharashtra, India,* ***aishwaryagotekar59@gmail.com***
[4]*Student, Department of Civil Engineering, J.D.I.E.T., Maharashtra, India,****tejaschute@gamil.com***

Abstract
This paper reports show that the using of copper slag as fine aggregate replacement in concrete. Many countries are witnessing a rapid growth in the construction industry which involves the use of natural resources for the development of the infrastructure. To reduce the use of natural aggregates as the main of aggregate in concrete, the aggregates which are generated from industrial wastes provides an alternative for construction industry. In this study we are using copper slag as a partial replacement to fine aggregates in concrete, in which cubes were casted for various grades of concrete and for various proportions of sand replacement with copper slag ranging from 20% to 50%. Obtained results on different parameters like strength, workability and density were compared with those of control concrete made with ordinary Portland cement and sand.

Index Terms*: concrete, copper slag, strength, density, workability*

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1. INTRODUCTION

1.1 General

India as itself is a developing country lots of construction activities are going on everywhere like skyscrapers ,roads, bridges ,dams etc and concrete is the base of all these construction activities. India itself consume 450 million cubic meter of concrete annually which approximate translates to 1 to 1.5 ton per Indian. But the important question that arises is, we have enough natural resources? Aggregates considered as one of the main constituent of concrete and occupy more than 70% of concrete mix. As so much fight is going on for obtaining Fine aggregates we have to find different alternative to this. Many by products and waste material like Quarry dust, Foundry sand, Sheet powder glass, copper slag, washed bottom ash are available and can be replace by sand .In this paper copper slag is used as a alternative to sand.

Copper slag is used in the concrete as one of the alternative Materials. Copper slag is a by-product obtained during matte smelting and refining of copper. For every tone of copper metal production, about 2 to 2.5 ton of waste slag is generated. Dumping or disposal of such huge quantities of slag cause environmental and space problems. During the past two decades, many attempts have been made by several investigators and copper producing houses all over the world to explore the possible utilization of copper slag. When it is introduced in concrete as a replacement material, it reduces the environmental pollution, space problem and also reduces the cost of concrete. However, further additions of copper slag whichcaused decreased in the strength due to an increase of the water content in the mix. Mixes with 80% and 100% copper slag replacement gave the lowest compressive strength value of approximately 80 MPa, which is almost 16% lower than the strength of the control mix. The results also demonstrated that the surface water absorption decreased as copper slag quantity increases up to 40% replacement; beyond that level of replacement, the absorption rate increases rapidly. Therefore, it is recommended that 40wt% of copper slag can used as replacement of sand in order to obtain with good strength and durability properties

1.2 Necessity

a. Copper slag it is the waste product of copper from sterlite industries India ltd, tuticorin.
b. The safe disposal of this waste is a lack, costly and causes environmental pollution.
c. Globally, the ready-mix concrete industry, the largest segment of the concrete

Market, is projected to exceed $100 billion in revenue by 2015

a. The construction site is the only place where the safe use of waste material (copper slag) is possible.
b. For every ton of copper production about 2-2.5 tons of slag is generated.

2. MATERIAL

2.1Cement

Ordinary Portland cement from Ultratech Company of 53 grades was used for this study. This cement is the most widely used one in the construction industry in India.

Table no.1: Test performed on cement

Initial setting time	65 minutes
Final setting time	231 minutes
Consistency	29.50
Fineness	8.50 % retained
Specific gravity	3.15
28 days compressive strength	56.86

2.2 Aggregate

Aggregate consists of large chunks of material ina concrete mix, generally a coarse gravel or crushed rocks suchas limestone, or granite, along with finer materials such as sand. Thefine aggregate used in this study is river sand conforming to grading zone II Table 1 of IS 383 The coarse aggregate used in this study isof angular in shape and the maximum nominal size of coarse aggregates 20 mmand it is Conforming to Table 2 of IS 383

Table no 2: Test performed on Coarse Aggregate

Water absorption	0.917
Specific gravity	2.917
Impact value	10.70
Crushing value	13.90
Zone	II

Table no 3: Test performed on Fine Aggregate

Fineness modulus	2.93
Zone	II
Water absorption	1.818
Specific gravity	2.653

2.3 Copper Slag

1. Copper Slag is the black glassy material, 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 2-2.5 tons of slag are generated.
2. Copper slag, a copper production residue, shows in its chemical composition high contents of aluminum, silica and iron oxides, similar to that of cement.
3. Additionally, its hardness and gradation seems to indicate its suitability for use as alternative aggregate for applications in construction products.
4. Copper slag is a by-product of copper extraction by smelting. During smelting, impurities become slag which floats on the molten metal. Slag that is quenched in water produces angular granules which are disposed of as waste or utilized
5. Slag from ores that are mechanically concentrated before smelting contains mostly iron oxides and silicon oxides.
6. Copper slag is mainly used for surface blast-cleaning. Abrasive blasting is used to clean and shape the surface of metal, stone, concrete and other materials. In this process, a stream of abrasive grains called grit is propelled toward the work piece. Copper slag is just one of many different materials that may be used as abrasive grit. Some of the variables which are affected by type of grit material are quality of surface finish, dust generated, and rate of grit consumption.

Table No 4: Physical properties of copper slag

Physical Properties	**Copper Slag**
Hardness on Mohr's Scale	6-7
Specific Gravity	3.51
Bulk Density	1.87
Particle Shape	Irregular
Appearance	Black and Glassy
Fineness Modulus	3.47
Angle of Internal Friction	51°20´

Table No 5: Chemical properties of copper slag

Chemical Composition	**Percentage**
Fe	42-48
SiO_2	26-30
Al_2O_3	1.0-3.0
Cu	0.6-0.7

Fig 1: Fine Aggregate and Copper Slag

3. CONCRETE MIX DESIGN

Copper slag in different proportions mixes with concrete as a partially or fully substitute for fine aggregates were prepared in order to investigate the effect of Copper slag substitution on the strength normal concrete. Cooper slag with different proportion mixes in concrete. Proportions (by weight) of Copper slag added to concrete mixtures were as follows: 0% (for the control mix), 20%, 25%, 30%, 35%, 40%, 45% and 50%. The control mixture was designed to have a target 28 day compressive strength of 20 N/mm2 (M- 20) and 30 N/mm2 (M-30), using a water cement ratio of 0.55 and 0.45.

3.1 Slump Test

Workability can be measured by the concrete slump test. The test is carried out using shape of a conical frustum known as a slump cone or **Abrams cone** that is open at both ends and has an attached handle. The tool has an internal diameter 100 mm at the top and 200 mmat the bottom with a height of 1 ft (300 mm).

Fig-2: Abram's Cone

Table No.6: Slump Results

% Replacement	M-20	% Increase	M-30	% Increase
CS 30	71	1.315	63	1.235
CS 35	73	1.352	68	1.333
CS 40	77	1.426	71	1.392
CS 45	81	1.500	78	1.529

3.2 Density Test

The density of concrete is a measure of its unit weight. It is simply a mass to volume ratio. Perhaps the easiest and most accurate way to calculate the concrete density is to measure some into a cube of known volume and weighing it. Fresh mix concrete pours into concrete moulds of standard size 150*150*150 mm. After setting of concrete, remold it and keep it in curing tank for 28 days. Once the curing period completes take it out and weighs it in Surface saturated manner. And after dividing this weight with the known volume of cube mould will get the density of concrete for 28 days.

Table No 7: Density Results

% Replacement	M-20	% Increase	M-30	% Increase
CS 30	2698.667	1.034	2722.963	1.032
CS 35	2742.815	1.051	2736.593	1.037
CS 40	2756.741	1.056	2757.926	1.045
CS 45	2769.481	1.061	2770.667	1.050

3.3 Strength Test

3.3.1 Compressive Strength:

Compressive strength is often measuredon a universal testing machine. By definition, the ultimate compressive strength of a material this value of uniaxial compressive stress reachedwhen the material fails completely. The compressive strength (N/mm2) is calculated by using the formula,

Compressive strength = Ultimate load N/Area of cross section mm

Table no.8: Compression Testing Machine

% Replacement	**3 Days**		**7 Days**		**24 Days**	
	mean	**%Increase**	**mean**	**%Increase**	**mean**	**%Increase**
CS 30	16.61	1.354	24.64	1.310	37.18	1.336
CS 35	16.94	1.382	25.48	1.355	38.53	1.385
CS 40	17.65	1.439	26.53	1.411	40.11	1.442
CS 45	16.51	1.346	24.77	1.317	37.11	1.334

Variation of Strength for various days with respect to normal concrete for M-20Grade

3.4 Ultrasonic Pulse Velocity Test

Ultrasonic Pulse Velocity (UPV) testing of concrete is based on the pulse velocity method toprovide information on the uniformity of concrete, cavities, cracksand defects. The test equipment must provide a means of generating apulse, transmitting this to the concrete, receiving and amplifying thepulse and measuring and displaying the time taken.

Table no.9: Ultrasonic pulse velocity test of cube for M40 grade of concrete

Replacement Of Fine Aggregate (%)	**7th Day**		**28th Day**	
	Velocity (Km/Sec)	**Concrete Quality**	**Velocity (Km/Sec)**	**Concrete Quality**
0	3.95	Good	4.26	Good
20	3.68	Good	4.54	Excellent
40	4.52	Excellent	5.21	Excellent
60	4.21	Good	4.83	Excellent

4. RESULTS

4.1 Slump

For lower percentage replace of copper slag workability is lower than higher percentage replacement. As percentage of copper slag replacement increases workability is also increases comparatively for 35 to 45 percentage replacement of copper slag, ,moderate workability is observed. For higher grade of concrete moderate workability is observed for little bit higher percentage of replacement of copper slag.

4.2 Density

For lower grade of concrete for 30% replacement of sand results into 35% more dense concrete. This percentage lowers down up to 32% in case of higher grade of concrete. As more copper slag replaces sand, concrete becomes denser which is observed in lower grade of concrete but for higher grade of concrete replacement of sand also affecting the density but relatively lower as compared with lower grade. For non structural and high density required construction replacement of higher percentage of copper slag may worked found better option. For example P.C.C, Curbs, Heavy mass concrete.

4.3 Strength

4.3.1 Compressive Strength

For lower grade of concrete 43.90% increase in strength of concrete is observed. Similarly 31.80% highest in the range for higher grade of concrete is noted for 40% replacement of copper slag. For 7 days strength the highest percentage increase is 41.10% and 34.4% for lower grade and higher grade of concrete respectively. For final strength the increase in percentage are observed as 44.20% and 35.50% for lower and higher grade of concrete respectively. From the observations and results obtained 40% replacement of copper slag gives highest strength in lower grade of concrete. Further increase in percentage of replacement copper slag reduces strength in lower as well as higher grade of concrete. Referring to earlier conclusions 40% replacement of copper slag is the optimum replacement for natural sand which gives comparatively 45 to 55 percentage dense concrete with moderate slump which is applicable for routine construction work.

4.4 Ultrasonic Pulse Velocity Measurement

The ultrasonic pulsevelocity measurement is the measure of quality of concrete. It is mainlyrelated to its density and modulus of elasticity which in turn, dependsupon the materials anddifferent proportion ofmix of used in making concrete aswell as the method of placing, compaction and curing of concrete. it was observed that the pulse wave velocity showedabove 4.5 km/sec at 7th day measurement and above 5.2 km/sec at 28thday measurement. This is due to the density of high mix and free from pores. It is also observed that the concrete at 40% replacementlevel showed excellent quality and good quality for other percentages at 7th day measurement at 28th day measurement, the concrete showed excellent quality for 20%, 40%, 60% and 80% replacement of fine aggregate and showed good quality for 0% and 100% replacement of fine aggregate. The important observation was that the addition of copper slag in concrete replacement of fine aggregate definitely reduced the pores and made the concrete impermeable.

5. CONCLUSIONS

1. The replacement of fine aggregate using copper slag fully or partially in concrete increases the density of concrete thereby increases the self-weight of the concrete

2. Form the results of compressive strength the concrete shown higher value at 40% replacement of fine aggregate using copper slag. So it is recommended that 40% of fine aggregate can be replaced by Copper slag.

3.As percentage of copper slag replacement increases workability is also increases comparatively for 35 to 45 percentage replacement of copper slag, ,moderate workability is observed.

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5. The ultrasonic pulse velocity test indicated the excellent quality of concrete at 40% replacement level

6.As percentage of copper slag replacement increases workability is also increases comparatively for 35 to 45 percentage replacement of copper slag, ,moderate workability is observed.

7. The construction site is the only place for safe use of waste materials, which reduces the environmental problems, space problems and cost of construction.

6. REFERENCES

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