Comparison of The Replacement of Natural Sand by Copper Slag on The Properties of Concrete (M30 & M40)

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Abstract - Sustained population growth and rapid industrialization have led to an increase in housing demand. Due to the environmental impact, the use of natural sand for concrete production is limited. The scarcity of mortar and concrete for the production of fine aggregates has been determined due to the partial replacement of gravel with copper slag. This paper reports some experimental studies on the effect of copper slag partially replacing sand on concrete performance. In this paper, an experimental work was carried out to investigate the effect of copper slag as a fine aggregate on the properties of concrete. For this work, copper slag is a byproduct of copper production, which contains large amounts of iron oxide and silicate and is chemically stable. In this study, an experimental work was carried out on M30 and M40 concrete for the entire study. Several concrete made from fine aggregate were treated with 0 to 100% (0%, 10%, 20%, 30%, 40%, 50%, 60%, 80%, and 100%). On hardened concrete, mechanical properties such as compressive strength, split tensile strength and flexural strength are determined. An evaluation of the water absorption test was also carried out. In addition, non-destructive testing (NDT) methods such as Ultrasonic Pulse Velocity (UPV) and Digital Schmitt Rebound Hammer (RH) testing were identified. Based on the test results, mechanical properties and non-destructive testing techniques, the results are in favor of industrial waste concrete and are compared with those of con- trolled concrete made from ordinary Portland cement and sand. Test results show that it is possible to use copper slag as a fine aggregate in concrete. The results of the concrete show that as the percentage of copper slag increases, the usability and density increase significantly compared to the control mixture. Replace copper slag can increase the weight of concrete samples. Therefore, it is recommended that copper slag be used as a sand substitute to obtain concrete with good strength and durability requirements.

Key words*: *Copper Slag, Compressive strength, Flexural strength, split tensile strength, non destructive tests, water absorption test.

I. INTRODUCTION

Copper slag is obtained as waste from the Sterlite industry. In the current circumstances, attention has been drawn to the environmental hazards posed by carbon emissions and sand mining and the serious imbalances in ecosystems. Various studies have been conducted to reduce the serious impact on the environment; the use of by-products such as copper slag as partial substitutes for fine aggregates. Have

There is a wealth of experience in using copper slag as a substitute for fine aggregates.

Our civilization is built on the beach. In addition to water and air, humble sand is the most natural resource consumed by mankind. More than 40 billion tons of sand and gravel are used each year. The amount of sand mined increased exponentially, but overuse of the material led to environmental problems, depletion of river sand deposits and material price increases. Developing countries like India are facing a shortage of high-quality natural sand, especially In India, natural ores have been exhausted and posed a serious environmental and social threat.

The use of industrial waste in concrete makes up for the lack of natural resources, addresses the disposal of waste, and looks for alternative technologies to protect nature. How much industrial waste is used to replace all or part of coarse or fine aggregates. The Indian National Bureau of Standards is the country's national standard body. Taking into account the scarcity of sand from natural sources, a variety of alternatives have been formed that ultimately aim to protect natural resources except encouraging the use of various wastes without compromising on quality. The use of alternative materials such as fly ash and slag not only helps to protect our precious natural resources but also enhances the durability of structures made from these materials. Copper slag, considered one of the wastes materials, may have broad prospects in the construction industry as a partial or complete replacement for cement or aggregates. Copper slag is mainly used for surface blasting.

II. LITERATURE REVIEW

Bose Christy Arunand Preethi Ramaswamy [1] studied onProperties of concrete partially replaced with copper slag as fine aggregate and ceramic tile waste as coarse aggregate & concluded that, experimental mixes of concrete M40with copper slag replacing fine aggregate in 0%, 20%, 40% and 60% was casted and tested. It was found that concrete with 40% Copper Slag content as fine aggregate and 10% Ceramic tile waste yielded best results both in strength and durability.(40% Copper Slag-0% Ceramic Tiles) had the highest chloride penetration indicating high durability. S.Kalaiyarasi, A. KrishnaMoorthy [2] worked onExperimental investigation on copper slag concreteobserved that by partially replacing sand with copper slag up to 40%, the compressive strength of concrete increased. For M35 grade mix concrete was used. The compressive strength was compared with control concrete. Compare the strength in 40% replacement of copper slag at 7, 28, and 60 days. M. V. Patil, Y.D.Patil [3] investigated on Effects of copper slag as sand replacement in concrete**,** for this research work, M30 grade concrete was used and tests were conducted for various proportions of copper slag replacement with sand of 0 to 100% in concrete. Mr. Neel, P.Patel etal [4] Effect of copper slag replaced with fine aggregate on durability properties of concrete, Test results shows that the durability properties of concrete has improved in sorptivity and water absorption but it should not able to resist in RCPT and Accelerated corrosion test and result of acid attack and Sodium chlorine attack concrete mix shows weaken strength and considerable weight loss which having copper slag as a partial replacement of sand (up to 40%) in concrete. When copper slag replaced with sand 40% it shows considerable high compressive strength than Conventional Concrete mix (CC).

M.Velumani, Dr.K.Nirmal Kumar[5]studied on Investigation on the Mechanical and Durability Properties of Concrete using Fly Ash and Copper Slag and observed that In durability studies, Rapid Chloride Penetration Test, Water Sorptivity Test and Water Absorption Test showed significant resistance to chloride penetration, Sorptivity and water absorption. The reason for significant improvement in compressive strength and durability could be attributed to pozzolanic activity and filler effect over the cementitious matrix effectively. Momin Aaquib, Jha Nilesh, Tanveer Ahmed etal [6]studied oneffect of copper slag as a sand replacement on the properties of concrete, this study reports the potential use of granulated copper slag from Sterile Industries as a replacement for sand in concrete mixes. In this work M40 grade concrete was used and different percentage replacement of sand by granulated copper slag were 0%, 10%, 20%, 30%, 40%, 50% and 60%.The results of compression & split-tensile test indicated that the strength of concrete increases with respect to the percentage of slag added by weight of fine aggregate upto 40% of additions. The recommended percentage replacement of sand by copper slag is 40% but when used beyond 50% results in decrease in strengths.Daniel C, Joel Shelton J etal [7] studied on Investigation on strength properties of self compacting concrete with copper slag as fine aggregate for M25 grade concrete**,** from the experimental results, it was observed that the compressive strength, split tensile strength and flexure strength of concrete can be improved by partial replacement of fine aggregate with copper slag and was found that 60% replacement gives optimum results.J. Ramesh Kumar, K. V. Ramana [8] studied on Use of copper slag and fly ash in high strength concrete, given that Concrete mixes were tested for workability, density, compressive strength, tensile strength, flexural strength. The workability of concrete increases with the increase of copper slag content in concrete mixes. This increase in the workability with the increase of copper slag quantity is due to the low water absorption characteristics of copper slagthe density of high strength concrete with the increase of copper slag quantity. The density of concrete was increased by almost 6%. It is recommended that 50 % of copper slag can be used as replacement of sand and 18% fly ash can be used as replacement of cement in order to obtain HSC with good fresh and mechanical properties. Kiran Kumar M S, RaghavendraNaik[9] worked on Experimental study on utilization of industrial wastes (red mud and copper slag) in mortar**,** The experimental work includes the following 2 parts: Part I: Investigating the effect of replacing a part of the cement binder with red mud in Mortar. Blended cement samples, six in number are prepared with replacement of cement by RM with increment of 5 percent (i.e. 5%, 10%, 15%, 20%, 25%&30%). It can be said that the 15 % replacement of cement by RM gives the maximum compressive strength as compare with the control mix after 3 days, 7 days & 28 days curing period. Part II**:** To study the effect of Red mud & Copper Slag (Replacement to Fine Aggregate) on compressive strength of mortar. In the second part of our investigation, fix the Copper Slag waste as constant (10%) replacement to fine aggregate and vary the Red Mud (5, 10, 15, 20,25 and 30%) replacement to cement, for the mix proportion 1:3 The cubes are cast and cured as per Indian standard codal provision and tested for compressive strength in the compression testing machine at different ages: 3, 7 and 28 days. Copper slag is replaced by 20 %, 40 %, 60 %, 80 % and 100 % of sand simultaneously with mineral admixture i.e., 5% to 30% of cement in the increment of 5 percent to study compressive strength, density, split tensile strength and corrosion properties. It is noticed that compressive strength of the concrete produced by replacing 10% cement by silica fume and 20% natural sand by copper slag shown the higher value as compared to other replacements. The concrete which was subjected to chloride attack/accelerated corrosion had shown 32.67% increase in the compressive strength for the above said replacements as compared to reference mix. The concrete which was subjected to accelerated corrosion has shown 22.22% increase in the split tensile strength for the above said replacements observed by Vishwa B Tipashetti, Shreepad Desai [10] in their studies on Evaluation on accelerated corrosion properties of the concrete produced by replacing sand by copper slag.

Srinivasu, Usha, &Nagasai [11] studied on compressive strength properties and effects of copper slag as partial replacement of fine aggregate in concrete. The Two different types of concrete grades M30 & M40 were used with different percentage of copper slag replacement from 0 to 100 percentages. The percentage replacement of sand was 0%, 10%, 20%, 30%, 40%, 50%, 60%, 80% & 100%. The concrete was tested for 7 days & 28days compressive strength after casting the moulds. Increased compressive strengths for the above grade of concretes were observed. For M30 grade concrete, the highest compressive strength was achieved at 7days by 50% replacement of copper slag is 39.105Mpa and the maximum compressive strength was achieved at 28days by 10% replacement of copper slag and which was found about 44.66MPa, compared with nominal mix (29.87N/mm^2 and 41.65N/mm^2) and for M40 grade concrete, the maximum compressive strength was achieved at 7days by 20% replacement of copper slag is44.44MPa and the highest compressive strength was achieved at 28days by 50% replacement of copper slag and which was found about 53.105MPa, compared with nominal mix (32.33N/mm^2 and 47.11N/mm^2).

III. MATERIALS USED

3.1 CEMENT

Portland cement in general, Portland cement (OPC) is by far the most important cement and other cementitious materials, such as fly ash and slag cement, used as a binder of the aggregate. The cement used in this study complies with the OPC 53 grade standard IS: 12269.

3.2 WATER

Water mixes with this dry composite to create a semi-liquid that workers can mold (usually by pouring it into a form). Concrete is solidified and hardened to a hard rock strength by a chemical process called hydration. Water reacts with the cement to bind the other components together to form a solid, stone-like material. This study uses good quality water.

3.3 COARSE AGGREGATE

Aggregate size greater than 4.75 mm is considered as coarse aggregates. It can be found from the original rock. Rough aggregate has different shapes, such as round, irregular or partially circular, angular, flake and so on. It should be free of any organic impurities, with negligible dirt content.

3.4 FINE AGGREGATE

Aggregate sizes less than 4.75 mm are considered fine aggregates. The sand should be free of any clay or inorganic material and be hard and durable.

3.5 COPPER SLAG

Copper slag produced from copper ores in pyrometallurgical production contains iron, alumina, calcium oxide, silica and the like. Copper slag is a by-product of copper extraction by smelting. In the smelting process, the impurities become molten slag floating on the molten metal. The slag hardened in water produces angular particles that are treated or used as waste. In this project, the copper slags used were supplied by Sterile Industries India Ltd, Hyderabad. Chemical traces present in the slag are harmless, such as copper, sulphate and alumina.

EXPERIMENTAL PROGRAM

The experimental plan aims to reduce the impact of destructive and non-destructive properties of concrete using copper slag as a partial replacement of 10%, 20%, 30%, 40%, 50% different proportions of fine aggregate, and 60%, 80% And 100%. For each test, the average of two samples from each mixture was tested at each ripening age and the average was used for the analysis. Compressive strength was calculated at 7 days and 28 days. The splitting tensile strength and flexural strength at 28 days of age were calculated.

IV. RESULTS AND DISCUSSIONS

4.1: MIX PROPORTIONS

The mixing ratio is based on IS-10262-2009. For specimens of grade 53 port land cement, natural sand and coarse aggregate, copper slag for the plant is being used. The experimental work was used to study the destructive and non-destructive testing of concrete, with the replacement of fine aggregate with copper slag for concrete grades M30 and M40.

The same split column tensile strength and prism bending strength of 28 days. After the water absorption test and non-destructive testing.

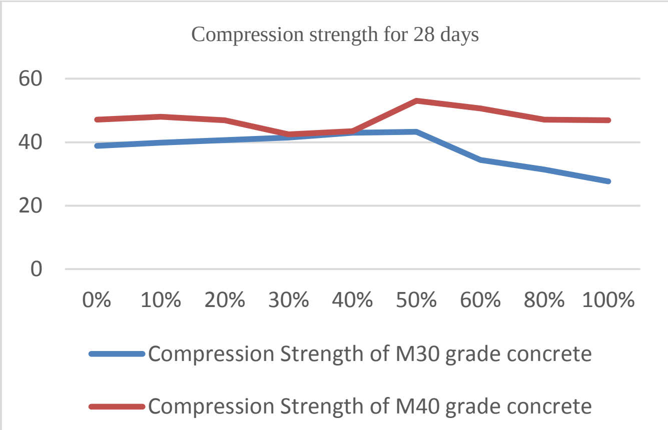
4.2: COMPRESSIVE STRENGTH

Using two different types of concrete grades, M30 and M40, copper slag replacement rates range from 0 to 100%. Sand replacement rates are 0%, 10%, 20%, 30%, 40%, 50%, 60%, 80% and 100%. The concrete was tested for 7 days and 28 days after casting mold. Compressive strength of the above grade concrete was observed to increase.

TABLE 1: COMPRESSIVE STRENGTH 28 DAYS OF

S.No	% replacement of copper slag	Split tensile strength after 28 days (N/mm^2)	
		M30 GRADE	M40 GRADE
1	0%	3.01	3.019
2	10%	3.32	3.329
3	20%	3.07	3.075
4	30%	3.45	3.456
5	40%	3.66	3.668
6	50%	2.50	2.469
7	60%	3.73	3.739
8	80%	3.31	3.315
9	100%	2.64	2.645

CURING FOR M30 & M40 GRADE CONCRETE



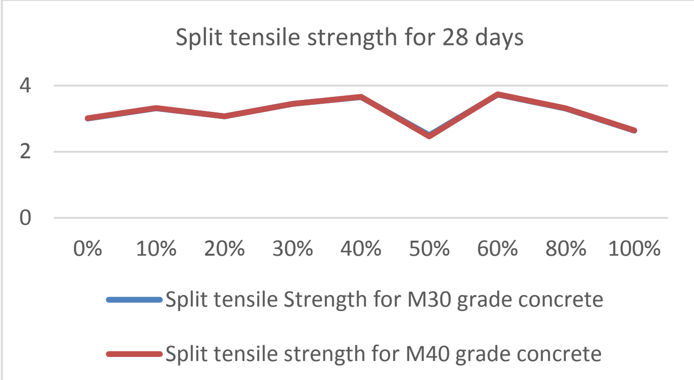
Graph 1.0: Showing The Compression Strength Results Of M30 & M40 Grade Concrete

4.3: SPLIT TENSILE STRENGTH TEST

The splitting tensile strength of the specimen is calculated by using **$T = 2P/\pi LD$**

S.No	% replacement of copper slag	Compressive strength after 28 days (N/mm^2)	
		M30 GRADE	M40 GRADE
1	0%	38.80	47.110
2	10%	39.89	47.995
3	20%	40.70	46.885
4	30%	41.44	42.440
5	40%	42.95	43.440
6	50%	43.33	53.105
7	60%	34.44	50.660
8	80%	31.39	47.105
9	100%	27.66	46.885

TABLE 2: SPLIT TENSILE STRENGTH 28 DAYS OF CURING FOR M30 & M40 GRADE CONCRETE

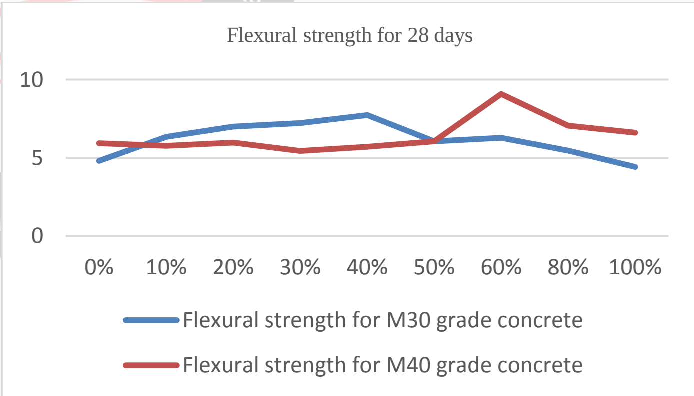


GRAPH 1.1: SHOWING THE SPLIT TENSILE STRENGTH FOR M30 & M40 GRADE CONCRETE

4.3: FLEXURAL STRENGTH TEST

TABLE 3: FLEXURALSTRENGTH 28 DAYS OF CURING FOR M30 & M40 GRADE CONCRETE

S.No	% replacement of copper slag	Flexural strength after 28 days (N/mm^2)	
		M30 GRADE	M40 GRADE
1	0%	4.80	5.931
2	10%	6.35	5.766
3	20%	7.00	5.983
4	30%	7.23	5.450
5	40%	7.73	5.703
6	50%	6.05	6.056
7	60%	6.27	9.094
8	80%	5.46	7.051
9	100%	4.42	6.606



Graph 1.2: Showing The Flexure Strength For M30 & M40 Grade Concrete

4.4: Water Absorption Test

Table4: Water Absorption Test Results For M30 Grade Concrete

S.No	Mix ID	saturated specimens(Kg)	weight of Oven dried specimens (Kg)	Saturated water absorption test at 28 Days (%)	
1	CC	8.390	8.093	3.678	3.620
		8.470	8.175	3.608	

		8.430	8.115	3.881	
		8.260	7.995	3.314	
2	20%	8.830	8.612	2.531	2.897
		8.570	8.208	3.153	
		8.440	8.170	3.304	
		8.640	8.421	2.600	
3	40%	9.190	8.830	4.077	4.343
		9.190	8.815	4.254	
		8.980	8.580	4.662	
		8.700	8.335	4.381	
4	60%	9.130	8.930	2.246	2.410
		9.200	8.915	3.196	
		8.930	8.820	1.247	
		9.070	8.810	2.951	
5	80%	9.270	9.140	1.422	1.347
		9.130	9.040	0.995	
		9.290	9.205	0.923	
		9.700	9.505	2.051	
6	100%	9.560	9.310	2.685	2.612
		9.630	9.345	3.049	
		9.370	9.270	1.078	
		9.890	9.543	3.636	

From table.4, it was observed that the slag admixed concrete showed lesser water absorption value than control concrete, when copper slag replace with sand up to 40%. Beyond 40%, the segregation and bleeding effect of copper slag concrete increases there by increasing the value of water absorption.

TABLE5: WATER ABSORPTION TESTRESULTS FOR M40 GRADE CONCRETE

S.No	Mix ID	Saturated Weight	Oven Dried weight	Saturated water absorption test at 28 Days (%)	
1	CC	8.510	8.445	0.776	1.506
		8.610	8.393	2.585	
		8.340	8.180	1.956	
		8.530	8.470	0.708	
2	20%	8.830	8.612	2.531	2.897
		8.570	8.308	3.153	
		8.440	8.170	3.304	
		8.640	8.421	2.600	
3	40%	8.770	8.676	1.083	1.384
		8.810	8.676	1.544	
		8.970	8.828	1.608	
		9.010	8.894	1.304	
4	60%	9.120	8.989	1.457	1.327
		8.900	8.720	2.064	
		9.460	9.444	0.169	
		9.280	9.132	1.620	
5	80%	9.270	9.140	1.422	1.347
		9.130	9.040	0.995	
		9.290	9.205	0.923	
		9.700	9.505	2.051	
6	100%	9.560	9.310	2.685	2.612
		9.630	9.345	3.049	
		9.370	9.270	1.078	
		9.890	9.543	3.636	

4.4: NON-DESTRUCTIVE TEST METHODS:

In hardened concrete, according to IS: 13311 rebound hammer test and ultrasonic pulse velocity test and other non-destructive testing.

Rebound hammer test:

A Schmidt Hammer, also known as a Swiss hammer or rebound hammer, is a device used to measure the elastic properties or strength of concrete or rock, primarily surface hardness and penetration resistance. Hammer measures the spring-loaded object's rebound on the sample surface. Rebound values can be used to determine compressive strength.

TABLE 6: RESULTS FOR REBOUND HAMMER TEST FOR M30 GRADE CONCRETE

Copper Slag added	Rebound Strength		Rebound Value		Compression Strength	
0%	59	34	53.7	45.2	780	700
20%	41.5	73.5	48.2	57.2	1400	1420
40%	38	90	46.8	60.3	1080	1200
60%	65.5	63	55.4	54.7	1380	1000
80%	31	43	43.7	48.7	1050	1000
100%	44.5	56.5	49.4	53	1020	1240

TABLE 7: RESULTS FORREBOUND HAMMER TEST FOR M40 GRADE CONCRETE

Copper Slag added	Rebound Strength		Rebound Value		Compression Strength	
0%	76.5	70.5	57.8	56.5	1540	1600
20%	89.5	71	60.2	56.6	1450	1150
40%	56.5	61.5	53.1	54.4	1230	880
60%	56.5	61	53	54.3	1040	1390
80%	45.5	34	52.3	58.3	880	1200
100%	28.5	32.5	48.9	51.2	765	820

Ultrasonic pulse velocity measurement:

Ultrasonic pulse velocity measurement is a measure of concrete quality. It is mainly related to the density and modulus of elasticity, which in turn depends on the material and mixing ratio used to make the concrete and the method of pouring, compaction and curing the concrete.

Table 7: Results For Ultrasonic Pulse Wave Velocity Test For M30 Grade Concrete

Copper Slag added	Distance mm	Time (µ Sec)	Pulse wave velocity (Km/Sec)	Average Pulse Velocity(Km/Sec)	Quality of concrete
0%	150	30.9	4.854	4.894	Excellent
	150	30.4	4.934		
20%	150	31.6	4.747	4.840	Excellent
	150	30.4	4.934		
40%	150	29.9	5.017	4.975	Excellent
	150	30.9	4.854		
60%	150	31.9	4.702	4.739	Excellent
	150	31.4	4.777		
80%	150	33.2	4.518	4.588	Excellent
	150	32.2	4.658		
100%	150	29.9	5.017	6.673	Excellent
	150	32.1	4.673		

Table 8: Results For Ultrasonic Pulse Wave Velocity Test For M40 Grade Concrete

Copper Slag added	Distance	Time (µ Sec)	Pulse wave velocity (Km/Sec)	Average Pulse Velocity (Km/Sec)	Quality of concrete
0%	150	29.2	5.137	5.094	Excellent
	150	29.7	5.051		
20%	150	29.4	5.102	4.978	Excellent
	150	30.9	4.854		
40%	150	29.4	5.102	4.962	Excellent
	150	31.1	4.823		
60%	150	30.4	4.934	4.918	Excellent
	150	30.6	4.902		
80%	150	30.3	4.823	4.829	Excellent
	150	31.6	4.836		
100%	150	30.4	4.934	4.894	Excellent
	150	32.2	4.854		

V. CONCLUSIONS

From the results and discussion, we draw the following conclusions.

1) The use of copper slag instead of fine aggregate in concrete increases the density of concrete, thereby increasing the weight of concrete.
2) From the results of compressive strength, tensile strength and flexural strength, concrete has a higher value when copper slag is used instead of 40% fine aggregate. So recommended
40% of the fine aggregate can be replaced with copper slag.
3) rebound hammer test gives a better rebound value
Then determine the compressive strength.
4) ultrasonic pulse wave velocity test shows that,
The quality of concrete is very good.
5) The availability of concrete increases with the increase of concrete
Fine aggregate copper slag content increased Under the same water-cement ratio to replace.

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