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Strength Evaluation of Copper Slag with Admixture for M40 Grade

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Abstract: Copper slag is the by-product of copper extraction process i.e. smelting, which floats on the surface of molten metal, which collected and disposed of or used as one of the waste which can have a promising future in construction industry as partial or full alternative of either cement or aggregates. A single ton production of copper produce around 2.2-3 ton of copper slag. It has several applications like land filling, construction of abrasive tool, roofing granules, cutting tools, rail road ballast material, concrete industry etc. These applications utilize solely regarding 15-20% of copper slag generated and the remaining material is dropped as a waste. so as to cut back the buildup of copper slag and additionally to produce an alternate material for sand and cement an approach has been done to analyze the utilization of copper slag in concrete for the partial replacement of sand and cement. Several researchers have already found it potential to use copper slag as a concrete aggregate, as a result of copper slag has identical particle size characteristics probably to it of sand. Fine-grained powder of copper slag is used as a supplementary cementing material to concrete and in cement clinker production. Although there are many studies that have been reported by investigators from other countries on the use of copper slag in cement concrete, not much research has been carried out in India concerning the incorporation of copper slag in concrete. M40 concrete was used to determine various mechanical properties. For sand replacement, five test groups (including control mixture) were constituted with replacement of 0% (control specimen), 25%, 50%, 75%, and 100% copper slag with sand in each series. The optimum proportion of replacement was found by conducting the following tests; Compressive strength test on mortar and concrete cubes & Durability of concrete specimens. The potential application of copper slag in concrete as a partial substitute for Portland cement. Four test groups were prepared with replacement of 0%, 7%, 14%, and 21% finely ground copper slag with cement in each series. To improvise the strength and reduce the setting time of concrete, hydrated lime is used as an activator to pozzolanic reaction. The compressive test was performed to study the mechanical behavior of copper slag admixed concrete for cement.
Keywords: Compressive strength, mix design, copper slag, split tensile strength, concrete, properties, replacement

I. INTRODUCTION

Copper slag has mechanical and chemical properties that make it significant to be used in concrete as a partial replacement for OPC or as an alternative for aggregates. For example, copper slag has favourable mechanical properties for aggregate purpose such as excellent soundness properties, better abrasion resistance and better stability reported by (Gorai et al 2003). Copper slag also exhibits pozzolanic properties since it contains lower amount of CaO (calcium oxide). On activation with NaOH (Sodium Hydroxide), it can exhibit cementitious property and can be used for partial or full replacement with portland cement. The utilization of copper slag for applications like ordinary portland cement replacement in concrete, or as a raw material has the dual advantage of getting rid of the cost for disposal and reducing the cost of the concrete. The use of copper slag in the production of concrete as a replacement with cement can have the advantage of minimizing the costs of disposal and help in safeguarding the environment. Despite the fact that several studies have been reported on the effect of copper slag replacement on the characteristics of concrete, further experimental studies are important to carry out in order to obtain a comprehensive understanding that would provide an engineering base to allow the utilization of copper slag in concrete.

II. METHODOLOGY

1) *Copper Slag:* Copper slag is a by-product material generated from the method of producing copper. Because the copper settles down within the smelter, it's a higher density; impurities keep within the prime layer and so are transported to a water basin with a low temperature for natural process. The top product may be a solid, arduous material that goes to the crusher for additional process.

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2) *Physical Characteristics of copper slag:* Copper slag is black glassy and granular in nature and includes a similar particle size vary like sand. The particular gravity of Indian slag lies between 3.4 and 4.1. The majority density of copper slag varies between 0.9 to 2.15 kg/m^3 that is sort of like the majority density of standard fine mixture. The free wetness content gift in slag was found to be but 0.5%. Gradation take a look at was conducted on copper slag and sand showed that each copper slag and sand had comparable particle size distribution as shown in Table 1.1 However, it looks that sand has higher fines content than copper slag. Tests to work out relative density and water absorption for copper dross and sand were administered in accordance with Indian Standards. The results show that copper slag includes a relative density of 3.91 that is above that of sand (2.6) and OPC (3.15). The sieve analysis report for numerous proportions of sand by copper slag. The presence of oxide within the slag is about 26 % that is fascinating, since it is one in each of the constituents of the natural fine mixture accustomed to traditional concreting operations. The fineness of copper slag on grinding is calculated to be 126 m^2/kg.
3) *Chemical Characteristics of Copper Slag:* Copper slag has found to be having higher constituents of SiO_2 and $Fe2O_3$ compared with OPC. Compared with the chemical composition of natural pozzolans of ASTM C 618-99, the summation of the 3 oxides (silica, aluminum oxide and iron oxide) within the copper slag is almost ninety fifth that exceeds the seventieth mark demand for sophistication N raw and calcined natural pozzolans. Therefore, copper slag is anticipated to own sensible potential to supply high-quality pozzolonas. The chemical constituents of copper slag which is obtained from National Council for cement and building materials, Ballabgarh, India, 2010.
4) *Mix Design:* The mix proportion chosen for this study is 1.25: 1.56: 2.71 with Water/Cement ratio of 0.40 shown in III.
5) *Cement:* OPC 53 Grade Ultra cement was used in this research. The quantity required for this work was assessed and the entire quantity was purchased and stored properly in casting yard. The following tests were conducted in accordance with IS codes.

Table I Tests on cement

1.	Specific Gravity	3.15
2.	Standard consistency	31.5%
3.	Setting time	
	(i) Initial setting time	57 minutes
	(ii) Final setting time	4 hours
4	Soundness test (Le- Chatelier’s test)	0.95 mm

6) *Fine Aggregate:* The fine aggregate used in this investigation was clean river sand and the following tests were carried out on sand as per IS: 2386- 1968 (III). The results of tests on sand are given in the Table V

Table II Tests on fine aggregate

1.	Specific gravity	2.6
2.	Percentage of voids	33.00%
3.	Fineness modulus	2.39
4.	Water absorption	1.25%
5.	Bulk density	1.71
6.	Sieve analysis	ZONE II

7) *Coarse Aggregate*: In the present investigation, locally available crushed blue granite stone aggregate of size 20 mm and down, was used and the various tests, carried out on the aggregates, are given below.The results of the tests on coarse aggregate are given in Table VI.

Table VI Tests on coarse aggregate

1.	Specific Gravity	2.6
2.	Fineness Modulus	7.10
3.	Percentage of Voids	39.01%
4.	Crushing Value	27.05%

8) *Water: In this research, potable water is used.*

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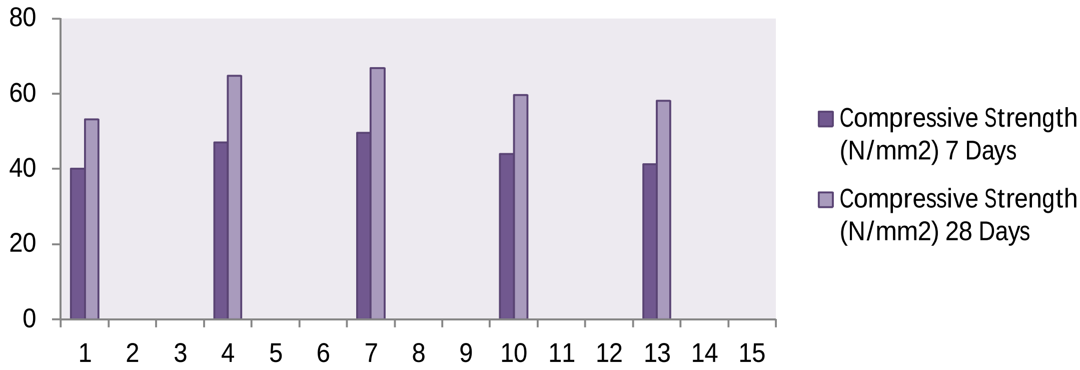
III. RESULTS AND DISCUSSIONS

A. Compressive Strength of Concrete Cubes



B. Split Tensile Strength Test On Concrete

S. NO.	Mix Identity	Ultimate Load (kN)	Average Ultimate Load (kN)	Split Tensile Strength (N/Mm^2)	Percentage Increase In Strength At 28 Days
1	CC	250	236.67	6.36	______
		240			
		220			
2	S_{25}	300	286.66	8.06	44.71
		280			
		280			
3	S_{50}	270	296.5	8.18	45.01
		280			
		340			
4	S_{75}	290	280	6.97	28.19
		270			
		280			
5	S_{100}	280	283.34	8.00	36.71
		280			
		290			

C. Compressive Strength of Concrete Cubes For Cement Replacement

S. NO.	Mix Identity	Ultimate Load (kN)	Average Ultimate Load (kN)	Split Tensile Strength (N/Mm^2)	Percentage Increase In Strength At 28 Days
1	CC	770	746.66	33.12	______
		720			
		750			
2	C_{07}	800	823.34	36.67	10.71
		830			
		840			
3	C_{14}	880	870.00	38.49	16.27
		860			
		870			
4	C_{21}	750	690.00	33.02	-0.3
		670			
		770			

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D. Split Tensile Strength Results Of Cylinders For Cement Replacement

S. NO.	Mix Identity	Ultimate Load (kN)	Average Ultimate Load (kN)	Split Tensile Strength (N/Mm^2)	Percentage Increase In Strength At 28 Days
1	CC	250	236.67	3.35	______
		240			
		220			
2	C_{07}	250	250	3.54	5.36
		240			
		260			
		270			
		260			
4	C_{14}	260	273.34	3.87	15.24
		280			
		280			
5	C_{21}	220	210	2.96	-11.35
		200			
		210			

E. Compression test on CMB specimens

S. NO.	Mix Identity	Ultimate Load (kN)	Average Ultimate Load (kN)	Split Tensile Strength (N/Mm^2)	Percentage Increase In Strength At 28 Days
1	CC	770	745.00	33.12	_____
		720			
		750			
2	CMB	880	853.34	37.89	14.45
		820			
		860			
3	S_{50}	1160	1055	46.79	41.34
		950			
		1055			
4	C_{14}	880	870	38.49	16.29
		860			
		870			

F. Split tensile strength of CMB and control specimens

S. NO.	Mix Identity	Ultimate Load (kN)	Average Ultimate Load (kN)	Split Tensile Strength (N/Mm^2)	Percentage Increase In Strength At 28 Days
1	CC	250	236.67	3.36	_____
		240			
		220			
2	CMB	240	250	3.54	5.36
		250			
		260			
3	S_{40}	270	296.7	4.18	25.06
		280			
		340			
4	C_{15}	260	273.34	3.85	15.24
		280			
		280			

IV. CONCLUSION

A. Replacement of copper slag (100% replacement with sand) will increase the self-weight of concrete specimens to the maximum of 15-18%.

B. The results of compressive, split tensile strength test have indicated that the strength of concrete will increase with relevancy the percentage of copper slag additional by the weight of fine aggregate up to 50% (S_{50}). More additions of copper slag caused a reduction in strength because of an increase of free water content in the mix.

C. The maximum compressive, split tensile strength was achieved at 14% (C_{14}) replacement to the weight of cement. There's an increase of compressive strength was achieved around 15.19% compared to control mixes. But, this can be 24% lower than S_{50} specimens. Similarly, for split tensile strength check, the strength was enhanced to 15.24% for C_{14} specimens compared to control mixes, whereas this can be 100 per cent lower than S_{50} specimens.

D. There is a rise of 14.48% of compressive strength in combination mixes (CMB) compared to the control mix. The compressive strength improvement is slightly lesser than S_{50} and C_{14} specimens, however, greater than C_{07} and C_{14} specimens.

E. There is an increase of 5.49% in split tensile strength for CMB mixes compared to regulate (CC) specimens. This price is 20% lower than S_{50} mixes and 100 percent under S_{14} specimens.

V. ACKNOWLEDGEMENT

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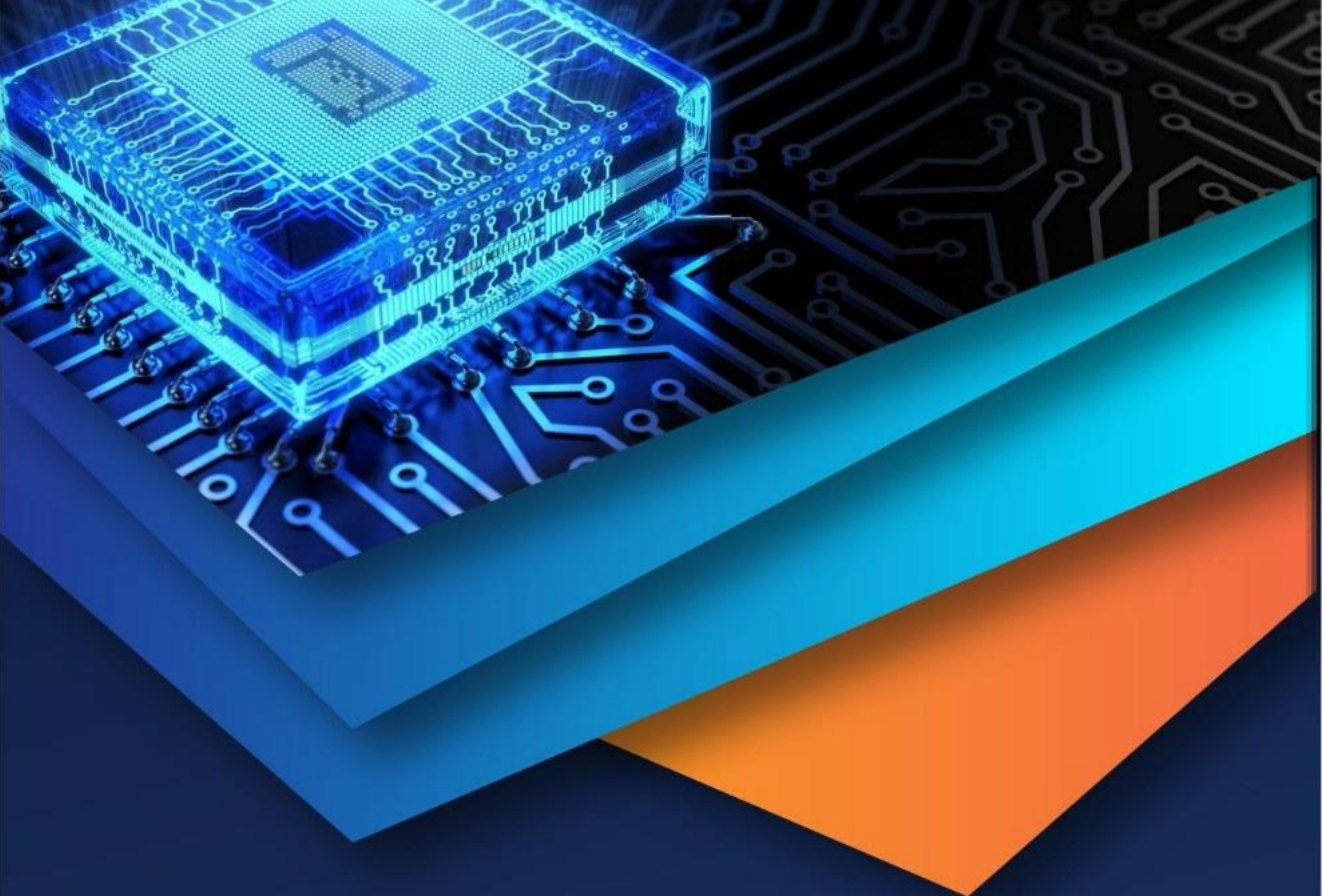

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