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International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Effects of Waste Copper Slag on the Mechanical Behavior Of Concrete: an Experimental Study

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ABSTRACT—

Cement and sand are major constituents of concrete. In manufacturing of concrete large quantity of the natural resources are used. There is great demand of material mainly from civil engineering industry for road and concrete constructions but now days it is very difficult problem in availability of material and also creates adverse effect on the environment. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for greenhouse effect and the global warming, hence it is inevitable either to search for another material or partially replace it by some other material. mainly from civil engineering industry for road and concrete constructions but now days it is very difficult problem for available of fine aggregates. So researchers developed waste management strategies to apply for replacement of fine aggregates for specific need. Natural resources are depleting worldwide while at the same time the generated wastes from the industry are increasing substantially. The sustainable development for construction involves the use of nonconventional and innovative materials, and recycling of waste materials in order to compensate the lack of natural resources and to find alternative ways conserving the environment. Copper slag is one of the materials that is considered as a waste material which could have a promising future in construction industry as partial or full substitute of either aggregates.

Keywords— Copper Slag, Fine Aggregate, Compressive Strength, Workability, Slump, Durability, Flexural Strength and Partial Replacement.,

I. Introduction

There is great demand of aggregates mainly from civil engineering industry for road and concrete constructions but now days it is very difficult problem for available of fine aggregates. So researchers developed waste management strategies to apply for replacement of fine aggregates for specific need. Natural resources are depleting worldwide while at the same time the generated wastes from the industry are increasing substantially. The sustainable development for construction involves the use of nonconventional and innovative materials, and recycling of waste materials in order to compensate the lack of natural resources and to find alternative ways conserving the environment. Copper slag is one of the materials that is considered as a waste material which could have a promising future in construction industry as partial or full substitute of either aggregates.

COPPER SLAG

Fig 1.- Copper slag

Copper slag is one of the materials that is considered as a waste material which could have a promising future in construction industry as partial substitute of either aggregates and cement. It is a by product obtained during refining of copper. Production of concrete using copper slag (ground) in place of cement (partial replacement) gives strength. It has good pozzalonic properties.

Table 1. Physical Properties of copper slag

Physical Properties	Copper Slag
Particle Shape	Angular
Appearance	Black & glassy
Type	Air cooled
Specific Gravity	3.5
Percentage of Voids	43.20%
Bulk Density	1770 Kg/m3
Fineness Modulus of Copper Slag	3.61

Table 2- % Chemical composition of copper slag

Chemical composition of copper slag	
Compound/property	Copper slag
Chemical analysis (%)	
Calcium oxide (CaO)	22.25
Silica (SiO2)	9.57
Alumina (Al2O3)	4.43
Iron oxide (Fe2O3)	57.42
Manganese oxide (MnO)	–
Magnesium oxide (MgO)	1.56
Sodium oxide (Na2O)	1.47
Potassium oxide (K2O)	–
Titanium dioxide (TiO2)	–
Sulfur trioxide (SO3)	–
Cu as CuO	1.24
Zn as ZnO	0.94
Pb as PbO	0.51
Ba as BaO	0.23
Ni as NiO	0.06

Table 3 %Chemical composition of cement

Chemical composition of Cement	
Compound/property	Cement
Chemical analysis (%)	
Calcium oxide (CaO)	62.89
Silica (SiO2)	20.19
Alumina (Al2O3)	3.84

Iron oxide (Fe2O3)	3.99
Manganese oxide (MnO)	0.2
Magnesium oxide (MgO)	3.56
Sodium oxide (Na2O)	0.2
Potassium oxide (K2O)	0.72
Titanium dioxide (TiO2)	0.26
Sulfur trioxide (SO3)	1.87
Cu as CuO	–
Zn as ZnO	–
Pb as PbO	–
Ba as BaO	–
Ni as NiO	–

Table 4 Mechanical and physical properties of cement

Mechanical and physical properties of cement.	
Tricalcium silicate (C3S) (%)	54.02
Dicalcium silicate (C2S) (%)	16.41
Tricalcium aluminate (C3A) (%)	4.01
3 day compressive strength (MPa)	18.2
7 day compressive strength (MPa)	28.5
28 day compressive strength (MPa)	42.6
Initial setting time (min)	85

OBJECTIVE

- To determine the optimum content of copper slag as replacement of fine aggregates in M40.
- To determine the optimum content of copper slag as replacement of cement in M40
- To determine Workability by Slump Test and Compaction Factor On fresh Concrete.
- To determine mechanical behavior such as Compressive Strength Test, Split Tensile Strength Test, Flexural Strength Test of hardened concrete.
- To find the durability of hardened concrete such as Sulphate Attack, Chloride Attack.

II. LITERATURE REVIEW

Khalifa et al. (2011) The impact of employing copper slag as a fine aggregate on the characteristics of cement mortars and concrete was investigated experimentally. The replacement of fine particles with copper slag in various mortar and concrete combinations ranged from 0% (for the control mixture) to 100%. Compressive strength was assessed for cement mortar mixtures, whereas density, workability, compressive strength, tensile strength, flexural strength, and durability were assessed for concrete mixtures. According to the results for cement mortars, all mixes containing various amounts of copper slag produced compressive strengths that were comparable to or greater than those of the control mixture.Also, compared to the control mixture, the compressive strength of mortars with a 50% substitution of copper slag increased by more than 70%. The findings for concrete showed that, compared to the control mixture, the density of the material increases only slightly, by about 5%, while the workability greatly increases as copper slag content increases. The strength of the combination was comparable to that of the control mixture when up to 40 to 50 percent copper slag was used instead of sand. Yet, when the amount of free water in the mixture increased with the addition of more copper slag, the mixture's strength decreased. The findings also showed that as copper slag content increased up to 50% replacement, surface water absorption reduced. In addition, the percentage volume of the permeable voids was comparable to the control mixture and the absorption rate increased quickly after that.To achieve concrete with high strength and durability requirements, it is advised that up to 40–50% (by weight of sand) of copper slag can be used as a replacement for fine particles.

Najimiet al. (2011) One of the several chemical processes that cause concrete to deteriorate is sulphate attack. Concrete constructions exposed to sulphate environments run the risk of experiencing negative chemical, microstructural, and physical changes that seriously deteriorate the concrete matrix and shorten its service life. One of the effective ways to increase concrete resistance against sulphate attack is to partially replace the cement with slag. This

paper examines the performance of concrete containing copper slag in sulphate solution. In this regard, concretes created by substituting 0%, 5%, 10%, and 15% of the cement with copper slag waste were the subject of an experimental investigation that included expansion measurements, compressive strength deterioration, and micro-structural analyses. The efficiency of copper slag replacement in enhancing concrete resistance to sulphate attack was highlighted by the study's findings.

Chavan et. al. (2013) - This work details an experimental programme to examine the impact of substituting copper slag for fine aggregate on the strength characteristics. Several replacement ratios of copper slag with sand, ranging from 0% to 100%, were tested in this research project using M25 grade concrete. By replacing 40% of the fine aggregate with copper slag and up to 75% of it, concrete's maximum compressive strength rose by 55%, outperforming the strength of a control mix.

Kharade et al. (2013) - In order to assess the mechanical properties of concrete mixtures in which fine aggregate (sand) was substituted with Copper Slag, an experimental inquiry was conducted, the findings of which are presented in this work. In place of the fine aggregates (sand), Copper Slag was added in weight percentages of 0% (for the control mixture), 10%, 20%, 30%, 40%, 50%, 60%, 80%, and 100%. The characteristics of both freshly laid concrete and hardened concrete were tested. At 7, 28, and 56 days, compressive and flexural strengths were assessed. According to the findings, workability rises as Copper Slag percentage does. According to test results, replacing fine aggregate (sand) in plain concrete with up to 80% copper slag significantly improves the material's strength qualities and allows it to be utilised in structural concrete applications.

Singh et al. (2014) - This study examined the mechanical characteristics of concrete that (partially) substituted copper slag for cement and came to the conclusion that 8% copper slag can achieve a satisfactory strength that is comparable to the control mix, but that anything more than that causes it to behave in a significantly different way.

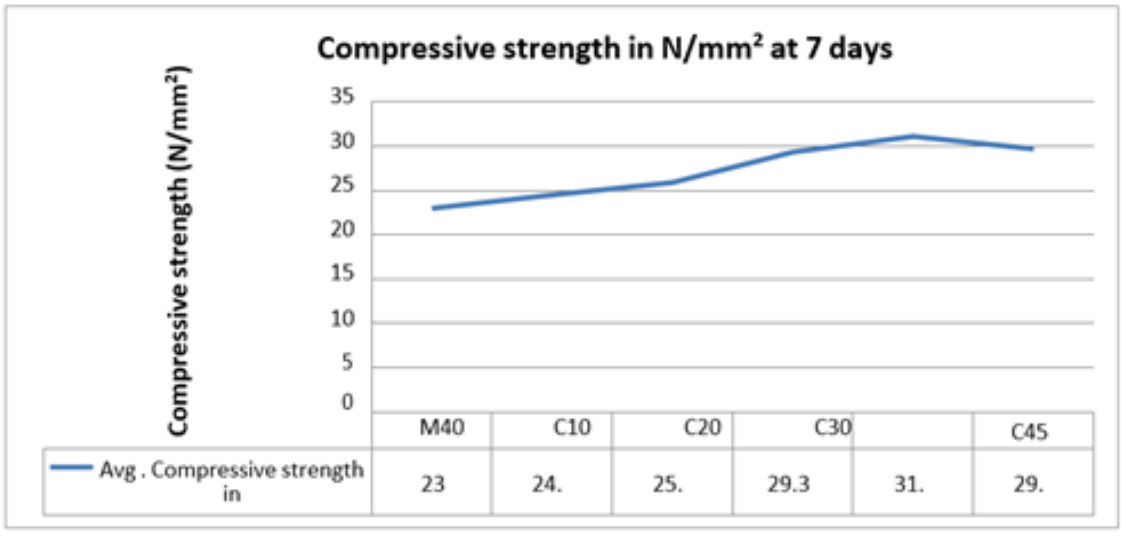
Gowda et al. (2014) - This research project primarily consists of replacing 0%, 35%, 40%, and 45% of the natural sand in M25 concrete with copper slag. the best result at 40% substitution of copper slag.

Muthaiyaa et al. (2014) – The goal of this study was to determine the ideal replacement level of fine particles with copper slag, and the results of the compression test showed that up to 40% of additions increased the strength of concrete.

III. EXPERIMENT AND METHODOLOGY

Table 5. Compressive strength in N/mm^2 at 7 days

Mix	Compressive strength in N/mm^2 at 7 days			Average Compressive strength in N/mm^2 at 7 days
M40	22	24	23	23
C10	24.1	25.4	24.2	24.5
C20	26.4	26	25.5	25.9
C30	29.8	30	28.2	29.33
C40	32.1	30.2	31	31.1
C50	29.9	30	29.4	29.7



Graph 1 Mix v/s compressive strength at 7 days

IV. Conclusions

- Maximum Compressive strength of concrete increased by 31.2%and 29.9% at 40% replacement of fine aggregate by copper slag at 7 and 28 days.
- Maximum split tensile strength of concrete increased by 27.6%and 21.3% at 30% replacement of fine aggregate by copper slag at 7 and 28 days.
- Maximum flexural strength of concrete increased by 23.2% at 30% replacement of fine aggregate by copper slag at 28 days.
- Compressive strength of concrete decreased by 8% and 6% at 8% replacement of cement by copper slag at 7 and 28 days.
- Split tensile strength of concrete decreased by 5% and 6% at 8% replacement of cement by copper slag at 7 and 28 days.
- Flexural strength of concrete decreased by3.1% at 8%replacement of cement by copper slag at 28 days
- Optimum content of copper slag is 40% by weight replacement of copper slag with sand in M40 mix.

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