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Copper or ferrous slag as substitutes for fine aggregates in concrete

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Abstract. The ever-increasing cost of natural sand and the environmental impacts of extracting manufactured sand (quarry sand) calls for exploring the potential to use alternative materials as fine aggregates in concrete. Copper slag and ferrous slag are industrial by products obtained from the smelting process of copper and iron respectively. A large quantity of copper slag and ferrous slag end up being disposed as waste in landfills and this poses a serious threat to the environment. Copper slag and ferrous slag have similar physical and chemical properties as natural sand and also exhibit pozzolanic activity. This paper studies the technical feasibility of industrial by-products such as copper slag and ferrous slag to replace the fine aggregate in concrete by evaluating the workability, strength and durability characteristics of concrete. The test results indicate that the strength properties are not affected by 40% or 100% replacement of quarry sand with iron slag or copper slag. However, 40% replacement of quarry sand with iron slag or copper slag in concrete is recommended considering the durability aspects of concrete.

Keywords: slag; concrete; replacement; strength; durability; fine aggregate

1. Introduction

Excessive mining of river sand for construction activities is a cause of serious environmental concern. The non-availability of natural sand and its increasing cost have led the construction industry to adopt alternate fine aggregate materials such as manufactured sand. Unrestricted quarrying for extracting aggregates causes quick depletion of naturally available resources and also results in large scale pollution of the environment. A sustainable solution for this problem is the utilization of waste materials to replace fine aggregates in concrete. Copper slag and ferrous slag are two industrial by-products having similar particle size and characteristics as that of natural sand.

Copper slag is a by-product material produced during the process of extracting copper from its ore. Around 33 million tonnes of copper slag is generated every year and India alone contributes around 6.0-6.5 million tonnes annually (Dash *et al.* 2016). Although copper slag is widely used in the sand blasting industry and in the manufacturing of abrasive tools, the balance is disposed off

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Table 2 Chemical composition of copper slag

Sl. No.	Chemical constituent	Copper slag
1.	Fe_2O_3	68.59%
2.	SiO_2	27.28%
3.	CaO	0.65%
4.	CuO	1.20%
5.	Al_2O_3	0.22%
6.	Na_2O	0.58%
7.	MgO	0.48%
8.	TiO_2	0.41%
9.	K_2O	0.23%
10.	SO_3	0.11%
11.	Sulphide Sulphur	0.25%

Table 3 Chemical composition of ferrous slag

Sl. No.	Chemical constituent	Ferrous slag
1.	SiO_2	37.34%
2.	CaO	37.73%
3.	Al_2O_3	14.42%
4.	MgO	8.71%
5.	Fe_2O_3	1.11%
6.	MnO	0.02%
7.	Sulphide Sulphur	0.50%

Sieve analysis and fineness modulus determination for all the aggregates were conducted as per IS: 383 (2016). The specific gravity of the fine aggregates was determined in accordance with the provisions of IS: 2386 Part III (1963).

The fine aggregate used in the study is manufactured sand (M-sand) having a specific gravity of 2.6. The fineness modulus of M-sand was obtained as 2.67 and was found to conform to Zone II. The M-sand grains are of angular shape.

Copper slag used in the study is air-cooled slag. The slag was found to have a black glassy texture. The shape of the copper slag particles is angular in nature. The physical properties of copper slag were determined by laboratory tests. The grading pattern of copper slag was determined by sieve tests and the sample was found to be well graded. The specific gravity was obtained as 3.3 and the fineness modulus as 2.84. The higher fineness modulus of copper slag indicates that the particles are coarser than M- sand. Table 2 gives the chemical composition of copper slag used in the study.

Air-cooled blast furnace ferrous slag was used for the study. It has a black/grey glassy appearance and has a similar particle size as that of sand. The ferrous slag particles have an angular shape. The physical properties were determined by laboratory tests. The specific gravity was recorded as 2.63 and the fineness modulus as 2.12. The sieve analysis of ferrous slag showed that the sample is well graded and has a lower fineness modulus compared to M- sand. Table 3 gives the chemical composition of ferrous slag used in the study. Fig. 1 shows the surface texture of copper slag and ferrous slag.