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Effect of Using Copper Slag as a Sand Replacement in Mortar

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ABSTRACT

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EFFECT OF USING COPPER SLAG AS A SAND REPLACEMENT IN MORTAR

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Abstract

There has been a significant rise in the importance in the sustainability and resource efficiency in the current construction industry. The aim of this study is to replace sand in mortar mixes by using waste copper slag from shipping industries. It examines how the compressive strength is affected when the waste copper slag replaces fine aggregate. The percentage replacement of sand by granulated copper slag were 0%,10%,20%,30%,40% and 50% by sand weight. There was an increase in the compressive strength of mortar by about 35-40%. The experimental investigation found that sand can be replaced by 40% of waste copper slag in the current study.

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1. Introduction

This research is to compare the compressive strength of conventional mortar and mortar mixed with copper slag. This project was focusing on testing mortars with different proportions of copper slag (10%, 20%, 30%, 40%, and 50% of sand weight).

Copper slag is a by-product obtained during smelting and refining of copper. The waste copper slag can be used as abrasive tools, road construction, and ballast [1]. Copper slag is known to be a hazardous waste which is categorized as Scheduled Waste 104 under the Department of Environment Malaysia report. Copper slag may be used in the construction industry as a filler to replace sand in mortar [10].

2. Literature Review

The strength behavior of concrete was studied by Brindha *et al* (2010) [4] by replacing sand with copper slag in the concrete manufacturing process. As results, it was found that the strength increases with 40% weight replacement of sand with copper slag. However, after this percentage, the strength decreased.

The durability properties of copper slag admixed concrete was studied by Brindha and Nagan (2011) [5] and they found that the control concrete had a higher resistance to the sulphuric acid solution (H_2SO_4) than the concrete with copper slag.

The impact of foundry sand in mortars and concrete was studied by Saveria Monosi *et al* (2010) [6] and they found that they could manufacture structural mortar and concrete with used foundry sand to partially replace natural sand. As a building construction material, the discarded foundry sand was recycled suitably for use.

The impact of using quarry dust as a partial replacement of sand in concrete was studied by Chandana Sukesh *et al* (2013) [7] and they found an increase in the performance of concrete in relation to its compressive strength.

3. Research Methods

3.1 Mortar Design Mix

There were 6 types of design mix. The first consisted of standard mix mortar currently being used in the industry as the control for the experiment. The following design

mixes were composed of different proportions of copper slag, which are 10 %, 20%, 30%, 40%, 50% of sand weight. For each design mix a set of three (3) cube samples of 100 mm length were made for the compression test. Another set of 3 cylinders and 3 cubes of length 50 mm were cast for the sorptivity and water absorption test.

Mortar used in this research was made with water, sand and cement with a ratio of 1:2.2:0.50 (cement: sand: water). Mortar grade suggested was of grade 3 which provides the highest compressive strength. Being used thoroughly as a joint between brick wall and many other purposes, grade 3 mortars should provide the strongest joint at 7.5mm thickness when used for masonry purposes.

3.2 Tests Conducted

Three main types of test have been conducted during this research, namely sorptivity test, water absorption test, and compression test.

3.2.1 Sorptivity Test

The sorptivity test measure the rate of absorption of water by capillary suction. For each proportion of copper slag added, a set of 3 samples is tested and the average is taken into consideration. Before testing, the specimens were kept in the oven for 48hours. After which it was kept for another 24 hours in desiccators at room temperature. The diameter of each sample was verified to be the same which is 100mm. the weight of each specimen was recorded to the nearest 0.1g. The bottom of the specimens was immersed in water and their weight was recorded at different time interval.

3.2.2 Water Absorption Test

The water absorption test is to help in determining the effective porosity of the specimen. Specimens were kept in oven for 36 hours, then in the desiccator for

further 24 hours. The samples were then tested at different time intervals.

3.2.3 Compressive Strength Test

A mixture of cement and sand having a ratio of 1:2.2 was prepared for this experiment. A water ratio of 0.50 was added to the mix, to provide a high workability for the mortar. The mortar was mixed using the conventional mortar mixer. The cubes formworks were oiled to allow easy removal of the specimens. After mixing, the (100 x 100 x 100) mm cubes were filled with mortar. To eliminate the presence of honey combing, the samples were then taken to the vibrator for 30 seconds. The samples were then allowed to set and were then placed in the curing tank before testing. For each percentage of copper slag added, a set of 3 samples were taken for testing and the average was taken into consideration.

Mortar cubes were tested after seven (7) days, fourteen (14) days and at (28) days of curing. Mortar cubes were levelled on top of the compression machine and load was applied on increasing manner until the cube is cracked uniformly.

4. Discussion and Conclusion

4.1 Physical Properties of Copper Slag

The physical properties of copper slag used in this research are shown in Table 1. It is observed that the high specific gravity of copper slag caused the increased of mortar's density.

Table 1: Physical properties of Waste Copper Slag

Appearance	Shiny, black, glassy, rough scratched surface
Particle shape	Angular, sharp, rough and colloidal
Density (kg/m ³)	2386.82
Water absorption (%)	19.1
Moisture content (g)	9.58
Specific gravity	3.49

4.2 Sorptivity and Water Absorption of Copper Slag Mortar

The results of sorptivity test and water absorption test are shown in Figure 1 and Figure 2 respectively. These tests have been conducted at 7 days, 14 days and 28 days curing age of the specimens.

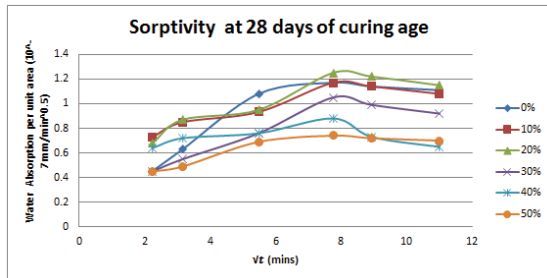


Figure 1. Sorptivity at 28 days of curing age

A lower water absorption by capillaries is made mortars consisting of 40% copper slag used as a partial sand replacement. The specimen was found to have finer pores. From the Figure 1, it may be seen that the replacement of sand by copper slag in the 20%wt samples, that it has absorbed more water than the conventional mix.

The mortar with 50% as percentage of sand replacement was analysed, it was found to have more pores than the specimen from the 40% sand replacement.

It was also observed that the rate of water absorption of the mortar specimen decreases as the curing age increases.

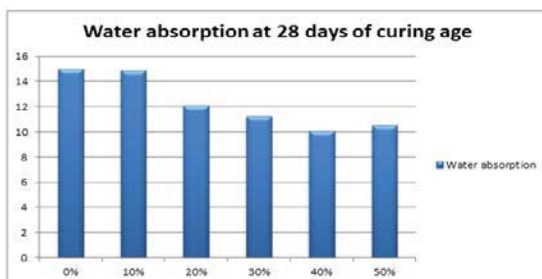


Figure 2. Water absorption at 28 days of curing

From Figure 2, it can be noticed that 40% of copper slag as a sand replacement is the best mix as it absorbed less water than the other samples.

4.3 Compressive Strength of Copper Slag Mortar

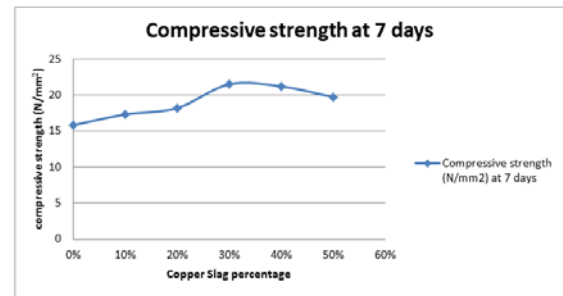


Figure 3. Compressive strength at 7 days

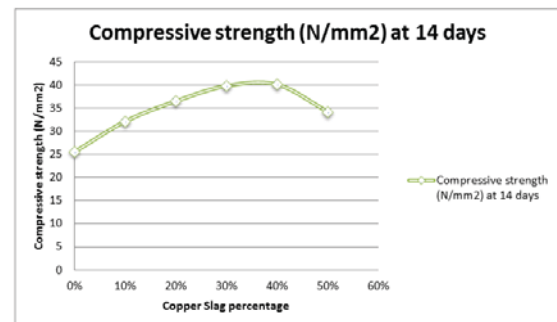


Figure 4. Compressive strength at 14 days

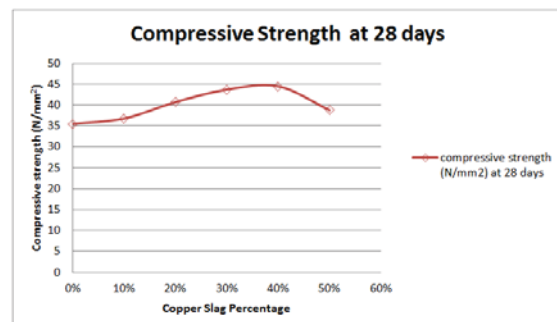


Figure 5. Compressive strength at 28 days

The density of the concrete mix has increased due to the usage of copper slag which has a higher specific gravity than sand.

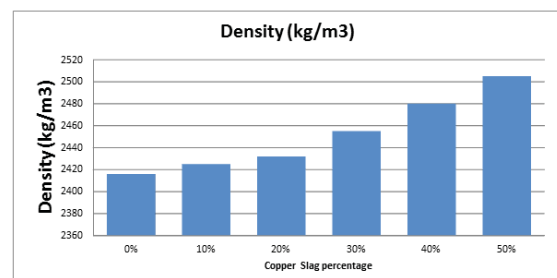


Figure 6. Density of mortar with copper slag

When the waste copper slag was added in the right amount to an optimum percentage

by weight of sand, it results as a remarkable increase in the compressive strength of mortar. The results from the Figure 6 show that the compressive strength of the mortar specimens has increased when a percentage of 35% to 40% of copper slag was added by proportionally reducing the amount of sand. However when 50% of copper slag was added to the mortar mix; the compressive strength decreases slightly but it was still higher than the conventional mortar, as illustrated in Figure 7.

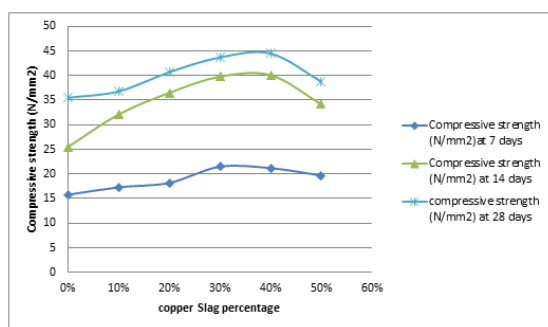


Figure 7. Compressive strength envelope

From the results of these experiments and research that has been conducted, the following conclusions may be drawn:

- The usage of waste copper slag in mortar increases its density thus increasing its self-weight.
- Waste copper slag definitely increases the compressive strength of mortar when used to a percentage of 40% added by weight of fine aggregate.
- The recommended percentage to use waste copper slag as a sand replacement is 35% to 40%.

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