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Strength and durability properties of cement mortar replaced by copper slag and green sand as fine aggregate – A Review

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Abstract—The acid attack on cement mortar, the cement mortar is replaced by copper slag and green sand replaced for river sand in equal proportions. The copper slag and green sand replaced by 0%, 10%, 20%, and 30% repectively. The specimen were cured for 28 days from the date of demoulding. The rest specimens were stored in acid solutions (HCl, H2SO4, HNO3) after 28 days of initial curing, and stored at laboratory temperature. Compressive strength tests, mass measurements took place for 24 hours.

Keywords—Mortar, Copper Slag, Green Sand, Acid Attack and Compressive strength.

I. INTRODUCTION

A. General

In India, there is great demand of aggregates mainly from civil engineering industry, for road and concrete constructions. But nowadays it is a very difficult problem for availability of fine aggregates. So the researchers developed waste management strategies to apply for replacement of fine aggregates for specific needs. 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. The rapid increase in the natural aggregates consumption every year due to the increase in the construction industry worldwide means that the aggregates reserves are being depleted rapidly, particularly in desert countries. It has come to our knowledge that, without proper alternative aggregates being utilized in the near future, the concrete industries globally consume 8-10 billion tons of natural aggregates, after some years that will be replenished.

Copper slag is one of the materials that are considered as a waste material which could have a promising future in the construction industry as partial or full substitute of either cement or aggregates. It is a by- product obtained during the matte smelting and refining of copper. To produce every ton of copper, approximately 2.2–3.0 tons copper slag is generated as a by-product material. In India copper slag is produced by many industries one of them is Sterlite Industries Ltd (SIL), Tuticorin Tamil Nadu. It is producing Copper slag during the manufacture of copper metal. Currently, about 2600 tons of Copper slag are produced per day and a total accumulation of around 1.5 million tons. If we are able to use the copper slag in place of natural sand, then we can successively obtain a material to replace the sand, which is eco-friendly and cost effective. Hence there is a growing need to find the alternative solution for the slag management.

Green sand is high quality silica sand with uniform physical characteristics. It is a by- product of ferrous and nonferrous metal casting industries, where sand has been used for centuries as a moulding material because of its thermal conductivity. The physical and chemical characteristics of foundry sand will depend in great part on the type of casting process and the industry sector from which it originates. In modern foundry practice, sand is typically recycled and reused through many production cycles.

In the casting process, moulding sands are recycled and reused multiple times. Eventually, however, the recycled sand degrades to the point that it can no longer be reused in the casting process. At that point, the old sand is displaced from the cycle as by-product, new sand is introduced, and the cycle begins again.

B. Objective Of Study

The objective of this investigation is

1) To study the influence of percentage of replacement of river sand by Copper Slag and Green Sand on the physical and chemical properties of Ordinary Portland Cement Mortar.
2) To study the acid attack on the cement mortar.
3) To study the absorption of various acid by the cement mortar for various mix ratios.
4) To study the compressive strength changes for various cement mortar mix subjected to attack of various acids.

C. Scope Of Study

This report will cover the physical and chemical properties of copper slag and green sand Ordinary Portland Cement Mortar and studying the enhancement of cement mortar produced by using Copper Slag and Green Sand replacement for River Sand

II. LITERATURE REVIEW

Kacha et al. (2014) concluded that all researchers gave their findings with concrete up to 30- 40% replacement of fine aggregate with foundry sand in which compressive and tensile strength were increased up to 20% whereas not much change occurred in modulus of elasticity. Also workability decreased with the increase of foundry sand content because of very fine particles.

Saraswati et al. (2013) reviewed that compressive strength kept on increasing with an increase on waste foundry sand and the maximum compressive strength had achieved at 60% replacement of fine aggregates. They also reviewed that split tensile strength decreased with increase in percentage of waste foundry sand.

Al-Jabri et al (2011) investigated the effect of using copper slag as a fine aggregate on the properties of cement mortars and concrete. Various mortar and concrete mixtures were prepared with different proportions of copper slag ranging from 0% (for the control mixture) to 100% as fine aggregates replacement. Cement mortar mixtures were evaluated for compressive strength, whereas concrete mixtures were evaluated for workability, density, compressive strength, tensile strength, flexural strength and durability. The results obtained for cement mortars revealed that all mixtures with different copper slag proportions yielded comparable or higher compressive strength than that of the control mixture. There was more than 70% improvement in the compressive strength of mortars with 50% copper slag substitution in comparison with the control mixture.

Najimi et al (2011) investigated the performance of copper slag contained concrete in sulphate solution. In this regard, an experimental study including expansion measurements, compressive strength degradation and micro structural analysis were conducted in sulphate solution on concretes. This was made by replacing 0%, 5%, 10% and 15% of cement with copper slag waste. The results of this study emphasized the effectiveness of copper slag replacement in improving the concrete resistance against sulphate attack. And also he demonstrated that, the mineralogical compounds of copper slag are pyroxene (CaZnSi2O6), fayalite (SiO4Fe2), anorthite (CaAl2Si2O8), quartz (SiO2) and magnetite (Fe3O4) similar to the main compounds of copper slag used in various researches, such as fayalite, magnetite and quartz.

Brindha et al. (2010) performed the replacement of sand by copper slag by 0%, 5%, 10%, 15%, 20%, 30%, 40% and 50%. The result showed that the compressive strength increased by 35-40% and the split tensile strength by 30-35%. The experimental investigation showed that percentage replacement of sand by copper slag shall be up to 40%. Copper slag is produced either by hydrometallurgically or pyrometallurgically production of copper from copper ores and contains materials like iron, alumina, calcium oxide, silica etc. The pyrometallurgically method is the only method applicable to ores containing copper-iron-sulphide minerals (such as chalcopyrite and chalcobornite), which are the most abundant. The waste material produced by the hydrometallurgical method is not considered as a slag.

Monosi et al. (2010) suggested that structural mortar and concrete can be manufactured with Used Foundry Sand as a partial replacement of natural sand. A suitable recycling of the discarded foundry sand as building construction material can be suggested from the work being carried out.

Saveria Monosi et al (2010) studied impact of Foundry Sand in Mortars and Concrete and found structural mortar and concrete can be manufactured with UFS as partial replacement of natural sand. A suitable recycling of the discarded foundry sand as building construction material was suggested.

Caijun Shi et al (2008) reviewed the characteristics of copper slag and its effects on the engineering properties of cement, mortars and concrete and they concluded that the utilization of copper slag in cement and concrete provides additional environmental as well as technical benefits for all related industries, particularly in areas where a considerable amount of copper slag is produced. When it is used as a cement replacement or an aggregate replacement, the cement, mortar and concrete containing different forms of copper slag have good performance in comparison with ordinary Portland cement having normal and even higher strength.

Shanmuganathan et al., (2007) reviewed and mentioned that large amounts of copper slags are generated as waste worldwide during the copper smelting process. Copper slag can be used in many applications such as concrete, landfills, Ballasts, bituminous pavements, tiles etc.

Turkel et al. (2007) investigated the influence of various acids on the properties of Pozzolanic cement mortars. Low concentrations of hydrochloric acid and nitric acid caused higher deterioration compared to sulfuric acid during the testing period. It should be noted that the sulfuric acid produced least soluble calcium salt and least damage on test specimens in terms of both strength and weight loss. The better performance of mortars against sulfuric acid attack can also be attributed to the low content of C3A cement.

Washington Almeida Moura et al (2007) presented the results of a study on the use of copper slag as pozzolanic supplementary cementing material for use in concrete. Specific gravity, compressive strength, splitting-tensile, absorption, and absorption rate by capillary suction and carbonation were investigated. The results pointed out that there is a potential for the use of copper slag as a supplementary cementing material to concrete production. The concrete batches with copper slag addition presented greater mechanical and durability performance .It is also concluded that, the addition of copper slag to concrete results in an increase on the concrete's axial compressive and splitting tensile strengths.

Nabil (2006) says Sulphate attack can also lead to leaching of calcium compounds, degradation of calcium silicate hydrate *(C-S-H)* and the overall deterioration of cement paste matrix.

Teik-Thye Lim and Chu (2006) conducted a study on the feasibility of using spent copper slag as fill material in land reclamation. The physical and geotechnical properties of the spent copper slag were first assessed by laboratory tests, including hydraulic conductivity and shear strength tests. The physical and geotechnical properties were compared with those of conventional fill materials such as sands. The potential environmental impacts associated with the use of the spent copper slag for land reclamation were also evaluated by conducting laboratory tests including pH and Eh measurements, batch-leaching tests, acid neutralization capacity determination and monitoring of long-term dissolution of the material. The spent copper slag was slightly alkaline, with pH 8.4 at a solid /water ratio of 1:1. The batch leaching test results showed that the concentrations of the regulated heavy metals leached from the material at pH 5.0. They were significantly lower than the maximum concentration for their toxicity limits referred by United States Toxicity Characteristic Leaching Procedure. They finally suggested that the spent copper slag was a good fill material and it can be used as a fill material for land reclamation.

Byung Sik Chun et al (2005) conducted several laboratory tests and evaluated the applicability of copper slag as a substitute for sand of sand compaction pile method.. From the mechanical property test, the characteristics of the sand and copper slag were compared and analyzed, and from laboratory model test, the strength of composite ground was compared and analyzed by monitoring the stress and ground settlement of clay, sand compaction pile and copper slag compaction pile.

Bipra gorai et al (2003) reviewed the characteristics of copper slag as well as pyro, hydro and combination of pyrohydrometallurgical methods for metal recovery. They also reported preparation of value added products from copper slag. The favorable physical, mechanical and chemical characteristics of copper slag lead to its application in various value added products such as cement, Land filling, aggregate, roofing granules, glass, tiles etc. They concluded that, application of copper slag reduces the cost of disposal and also reduces environmental pollution.

Gorai et al., (2003) have been reviewed the characteristics and utilization of copper slag. The apprehension of environmental hazard from the viewpoint of leaching of heavy metals from the slag and its long-term stability in extreme environmental conditions is studied and reported from their sulphuric acid leaching results that the heavy metals present in the slag are very stable and has poor leach ability. They suggested that the slag is safe to be considered for use in a wide variety of applications such as for Portland cement, building materials such as tiles and bituminous pavement constructions. The slag samples are non-toxic and pose no environmental hazard.

Ayano and Sakata (2000) critically reviewed the characteristics of copper slag and its effects on the engineering properties of cement, mortars and concrete. They reported that the shrinkage of specimens containing copper slag fine aggregate was similar to that of specimens without copper slag.

Hobbs and Matthews (1998) pointed out that the reduction in water to cementitious ratio improves the acid resistance.

Grube and Rochenberg (1989) studied the durability of concrete structures in acidic water and they also proposed the mechanism of acid attack in which carbon dioxide dissolved in water first forming a thin layer of calcium carbonate very close to the surface in the paste. Additional carbon dioxide leads to the formation of calcium bicarbonate which is soluble in water. The same process happens in case of calcium, forming calcium silicates which are again soluble. Hydrous silicon dioxide gel layer remains also containing aluminium and iron. This layer becomes thicker with the increase in level of attack and due to the weak interaction of

paste with the aggregates, aggregates come out of their place under mechanical action. However, the rate of concrete removal does not increase if the aggregate particles within the gel layer remain in place being held; for instance by the surrounding soil.

Fattuhi and Hughes (1988) determined the performance of cement paste subjected to sulphuric acid. According to them sulphuric acid largely occurs in industrial environments. However, random spillage, unscheduled washing down, leakages, irresponsible dumping of chemical waste are the main sources of severe sulphuric acid attacks. In natural ground water sulphuric acid is likely to be found as a result to the oxidation of sulphuric minerals such as pyrites and marcasiste, a process which is catalyzed by the presence of aerobic bacterium, thiobacillus ferro-oxidans. During exposure of concrete to sulphuric acid or acidic water, the calcium hydroxide reacts with the sulphuric acid to form gypsum, which can be readily washed away.

Lea, (1988) says acids are damaging to concrete. In case of acid attack there are no complex reactions generated as the case for sulfate attack. However, in case of acid attacks soluble compounds are dissolved which destroys the crystalline structure and leaving behind only incoherent residue. The attack increases with an increase in pH values which is logarithmic function of the hydrogen ion. The rate of attack also depends on the rate of diffusion of hydrogen ions through the cement gel (C-S-H) after calcium hydroxide has been dissolved and leached out.

Harrison (1987) concluded that there was a slower rate of acid attack on concrete with reduced lime content.

III. CONCLUSION

Copper slag which is an industrial waste product can be used as replacement for cement and sand and contributes to the increase in various mechanical properties of cement mortar. Copper slag can be used upto 30% but when used beyond 50% results in decrease in strengths.

Green sand which is an waste form moulding can be replaced upto 30%, which does not change any properties of cement mortar. If it replaced more than 30%, it will change the strength of the cement mortar.

The acid curing is to be done for 10% of dilute acid and kept curing for 24 hours by mixing it with one by third of the water for curing.

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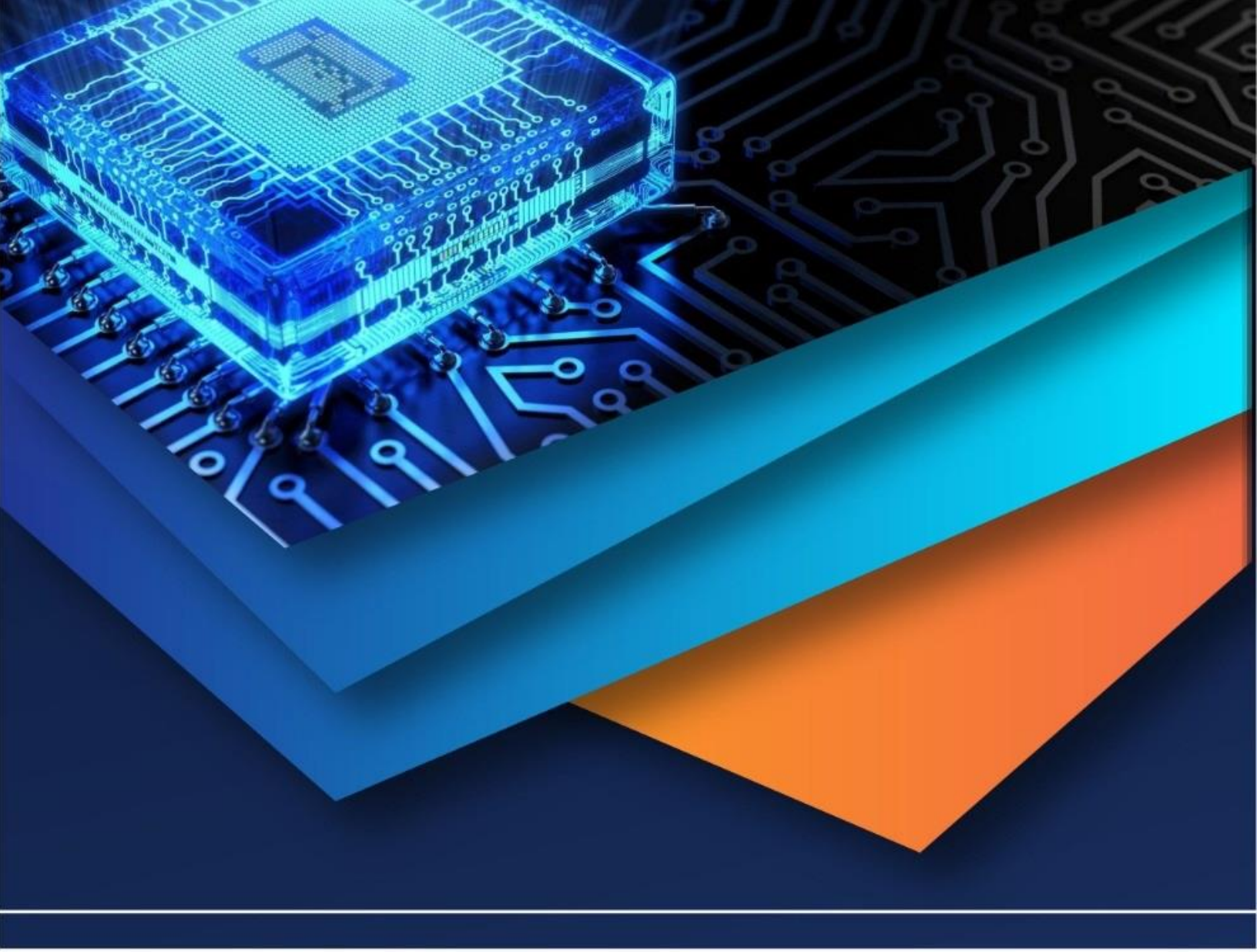

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