COPPER SLAG IN CONCRETE AS REPLACEMENT MATERIAL

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ABSTRACT

Copper slag is an industrial by-product material produced during the process of manufacturing of copper. About 2.2 tonnes of copper slag is generated, for every ton of copper production. The primary objective of this paper is to study the application of copper slag as an alternative replacement material of sand. This paper also studies the effect of replacement of Fine aggregate with copper slag on mechanical properties of concrete.

KEY WORDS: Copper Slag, Concrete, Properties, Durability, Sand Replacement

1.1 INTRODUCTION

Protecting the depleting natural sand resource and the shore line is a major concern of the day. It is essential today, to reduce excessive consumption of the natural river sand and there by prevent sand mining. It is possible by utilization of industrial by-products as well as other waste materials in the production of normal concrete and HSC. These products can be used as partial and/or full replacement of cement or and aggregates or as admixtures. Also, many times, it was found that concrete made with wastes and industrial by-products possesses superior properties than the conventional concrete in terms of strength, performance and durability. Hence, in this paper, copper slag is explored to find its suitability as a replacement material for fine aggregate in making concrete.

Large quantities of waste materials are being generated by various industries and disposal of waste materials is causing environmental and health hazards. For many years, Industrial by-products such as fly ash, silica fume and slag were considered as waste materials. Application of these materials as replacement for cement and sand in Concrete showed improvement in workability and durability compared to normal concrete and has found their application in the many structures. In the recent past, intensive research studies have been carried out to explore all possible recycling and reuse methods. Construction waste, blast furnace Slag, steel slag, coal fly ash and bottom ash have been accepted in many places as alternative aggregates in embankment, roads, pavements,
foundation and building construction, raw material in the manufacture of ordinary Portland cement as pointed out by Teik thye luin et al (2004).

The world copper production is currently about 14.98 million tonnes (International Copper Study Group, 2005) and it is estimated that for every tonne of copper produced, about 2.2 tonnes of copper slag is generated as a waste (Gorai et al., 2003).

Around 24.6 million tons of Copper slag is generated from the world copper industry (Gorai et al 2003). Though some portion of copper slag is widely used in the sand blasting and in the manufacturing of abrasive tools, the remainder is disposed of without any further reuse or reclamation.

Copper slag, because of its mechanical and chemical characteristics such as excellent soundness characteristics, good abrasion resistance and good stability, as reported by Gorai et al, 2003, is found to be suitable for use in concrete as a partial replacement for Portland cement or as a substitute for aggregates. Copper slag also exhibits pozzolanic properties since it contains low CaO. By activation with NaOH, it can exhibit cementitious property and can be used as partial or full replacement for Portland cement.

The use of copper slag in the concrete as a replacement for fine aggregate, reduces the costs of disposal, lowers the cost of the concrete and also helps in protecting the environment. Despite the fact that several studies have been reported on the effect of copper slag on the properties of Concrete, further investigations are necessary in order to obtain a comprehensive understanding that would provide an engineering base to allow the use of copper slag in concrete.

1.2 LITERATURE REVIEW

Copper slag is a by-product obtained during matte smelting and refining of copper. One of the greatest potential applications for reusing copper slag is in concrete production

Concrete, is the most versatile construction material. Engineers are continually working on it, to improve its performance with the help of innovative supplementary or replacement materials. Usage of new materials in concrete, which are by products from industries and other processes, not only helps in utilizing these waste materials but also enhances the properties of concrete in fresh and hydrated states. The usage of industrial slags, which are waste industrial by-products, in concrete is an important study today, of National and International interest. In the present status, research on copper slag concrete is yet to get momentum in our country.

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. The characteristics and utilization of copper slag have been reviewed (Gorai et al., 2003). 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 by Shanmuganathan et al., and reported from their sulphuric acid leaching results that the heavy metals present in the slag are very stable and have poor leachability. 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.

R R Chavan & D B Kulkarni (2013) conducted experimental investigations to study the effect of using copper slag as a replacement of fine aggregate on the strength properties and concluded that Maximum Compressive strength of concrete increased by 55% at 40% replacement of fine aggregate by copper slag and flexural strength increased by 14 % for 40 % replacement.

Many researchers have investigated worldwide on the possible use of copper slag as a concrete aggregate. Some of the important and published works are reviewed and presented briefly below.
Wei Wu et al (2010) investigated the mechanical properties of high strength concrete replacing fine aggregate with copper slag. Micro silica was used to supplement the cementitious content in the mix for high strength requirement. They observed that when copper slag was used to replace fine aggregate, up to 40% copper slag replacement, the strength of concrete was increased while the surface water absorption decreases. They also observed that when more than 40% of copper slag is used, the microstructure of concrete contains more voids, micro cracks, and capillary channels which accelerate the damage of concrete during loading.

Al-Jabri et al (2009, 2011) investigated the performance of high strength concrete made with copper slag as a replacement for fine aggregate at constant workability and studied the effect of super plasticizer addition on the properties of High Strength Concrete made with copper slag. They observed that the water demand reduced by about 22% for 100% copper slag replacement. The strength and durability of High Strength Concrete improved with the increase in the content of copper slag of up to 50%. However, further additions of copper slag caused reduction in the strength due to increase in the free water content in the mix. Also, the strength and durability characteristics of High Strength Concrete were adversely affected by the absence of the super plasticizer from the concrete paste despite the improvement in the concrete strength with the increase of copper content. The test results also show that there is a slight increase in the density of nearly 5% with the increase of copper slag content, whereas the workability increased rapidly with increase in copper slag percentage.

Caijun Shi et al (2008) reviewed the effect of copper slag on the Engineering properties of cement mortars and concrete. They reported that the utilization of copper slag in cement mortar and concrete is very effective and beneficial for all related industries, particularly in areas where a considerable amount of copper slag is produced. It proved both environmental as well as technical benefits. They observed that there was more than 70% improvement in the compressive strength of mortars with 50% copper slag substitution.

Byung Sik Chun et al (2005) conducted several laboratory tests and evaluated the applicability of copper slag as a partial replacement for sand. From the various tests performed, the strength of composite ground was compared, studied, and analyzed by monitoring the stress and ground settlement of clay, sand compaction pile and copper slag compaction pile.

Teik-Thye Luin and Chu (2004) studied the feasibility of using spent copper slag as fill material in land reclamation. After conducting many laboratory tests, they finally concluded that the spent copper slag was a good fill material and it can be used as a fill material for land reclamation. The physical and geotechnical properties of the copper slag were assessed by laboratory tests and were compared with sand. The potential environmental impacts of using copper slag for land reclamation were evaluated by pH and Eh measurements, batch-leaching tests, acid neutralization capacity determination and monitoring of long-term dissolution of the material. The copper slag was found to be 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.

Mobasher et al (1996) investigated the effect of copper slag on the hydration of cement when up to 15% of copper slag replaced Portland cement. By X-Ray diffraction and the porosity hydration reactions were examined using mercury intrusion porosimetry and it so found that there is a significant increase in the compressive strength for up to 90 days of hydration. A decrease in capillary porosity measured using MIP indicated densification of the microstructure. Addition of copper slag decreased the Fracture properties such as critical stress intensity factor and fracture toughness.

Arino and Mobasher (1999) presented the effect of ground copper slag on the strength and fracture of cement-based materials. Portland cement was replacement with ground copper slag up to
15% by mass. By closed-loop controlled compression and three-point bending fracture tests, it is observed that, the compression test utilized a combination of the axial and transverse strains as a control parameter to develop a stable post-peak response. A cyclic loading-unloading test was conducted on three-point bending notched specimens under closed-loop crack mouth opening control. The test results indicated that GCS concrete was stronger but more brittle than ordinary Portland cement concrete. Fracture test results confirmed the increased brittleness of concrete due to the use of GCS. Long-term results showed equal or higher strengths for the GCS specimens without concern for degradation of other properties.

Sioulas and Sanjayan (2000) reported the results of use of slag blended cements in the production of High Strength Concrete. Slag replacement can assist in reducing high hydration temperatures, which is a problem in concrete with high cement contents. Slag replacement levels were of 70%, 50%, 30% and 0%. A ternary blend, containing Portland cement, slag and silica fume was used in square columns of size 800 x 800 mm in cross-section and 1200 mm high. They concluded that the peak and net temperature rise encountered at the center of the columns are substantially reduced with the inclusion of slag into the binder. The time required to attain peak temperature is delayed with the inclusion of slag into the concrete. Introduction of slag significantly reduced the maximum thermal gradients exhibited by the columns.

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 strength, 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.

Ayano Toshiki et al (2000) studied the problems in using copper slag as a concrete aggregate. Excess bleeding is one problem which is attributed to the glassy surface of copper slag. Another problem is the delay of setting time of concrete which is more than a week sometimes and they concluded that the delay of setting time does not have a negative influence on durability.

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.

Ke Ru Wu et al (2001) studied the effect of copper slag as coarse aggregate in high-performance concrete on mechanical properties of concrete. Tests were carried out to study the effect on the compressive strength, splitting tensile strength, fracture energy, characteristic length, and elastic modulus. Concrete of compressive strengths 30, 60 and 90 N/mm\(^2\) were used in the study respectively. Quartzite, crushed granite, limestone, and marble coarse aggregate were used in the study. The results showed that the strength, stiffness, and fracture energy of concrete for a given water/cement ratio (W/C) depend on the type of aggregate.

Mosafa Khanzadi and Ali Behnood (2009) investigated the feasibility of using copper slag as coarse aggregates in high-strength concrete. The effects of replacing limestone coarse aggregate by copper slag coarse aggregate on the compressive strength, splitting tensile strength and rebound hammer values of high-strength concretes are evaluated in this work. The use of copper slag aggregate showed an increase of about 10–15% compressive strength and an increase of 10–18%
splitting tensile strength when compared to limestone aggregate indicating that using copper slag as coarse aggregate in high-strength concrete is suitable.

Goni et al (2002) studied the reactivity of hydrated portland cement pastes, microstructural and mechanical properties of the composite material containing up to a 30% of a Spanish ground copper slag in an aggressive solution, were studied Flexural strength data, X-ray diffraction as well as porosity and pore-size distribution analyses.

Najimi et al (2011) investigated the performance of copper slag in concrete in sulphate solution. An experimental investigation on expansion measurements, compressive strength degradation and micro structural analysis were conducted in sulphate solution on concretes by replacing 0%, 5%, 10% and 15% of cement with copper slag waste. The results of this study emphasized the effectiveness of copper slag in improving the concrete resistance against sulphate attack.

Although some studies have been done to investigate the potential of using copper slag as a sand replacement material, significant knowledge gaps still exist. There is a need for more research in India in this area.

1.3 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 concrete. Copper slag can be used upto 30% but when used beyond 50% results in decrease in strengths.

REFERENCES


