A REVIEW ON PARTIAL SUBSTITUTION OF SAND WITH COPPER SLAG ON MECHANICAL AND DURABILITY CHARACTERISTICS OF HIGH PERFORMANCE CONCRETE

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ABSTRACT. Sustainability and resource efficiency are becoming increasing important issues within today's construction industry. Many countries are witnessing a rapid growth in the construction industry, which involves the use of natural resources for the development of infrastructure. This growth poses a threat to natural resources that are available. Copper slag is considered as waste material and can be used as replacement of fine aggregates. The possibility of substituting natural fine aggregate with industrial by-products such as copper slag offers technical, economic and environmental advantages which are of great importance in the present context of sustainability in the construction sector. Sand is a natural resources and depletion of sand is a big issue for environment. So it is necessary to protect environment and reduction of waste by recycling and reusing of waste materials. This paper focused on the development of high performance concrete by replacing sand by copper slag and to find out the optimum solution of waste replacement in concrete by studying various authors researches and reviews. The primary objective of this paper is to study the application of copper slag as an alternative replacement material of sand by copper slag on mechanical and durability performances of HPC. Earlier research at the modes of utility of this waste material and subsequent picks up in strength and quality of concrete has been condensed in this paper.

Keywords: Durability, Sustainability, Copper slag, Sand, High Performance Concrete

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INTRODUCTION

Concrete is the most important building material used and produced 10 billion cubic yards worldwide each year. The reasons for the popularity of concrete is its excellent mechanical and durability properties if properly designed and produced. It is readily available and affordable material which is easily moldable, adaptable, relatively fire resistant. Its most intriguing characteristics is the fact that it is an engineered material satisfying almost any reasonable set of performance specifications than any other currently available material. (Meyer,2009). High performance concrete (HPC) is a concrete mixture possessing high durability and high strength as compared to Conventional Cement Concrete(CCC). This concrete contains one or more of cementious materials such as fly ash, Silica fume or metakaolin and usually a super plasticizer. The use of some mineral and chemical admixtures like silica fume and super plasticizer enhance the strength, durability and workability qualities to a very high extent(Priti et al, 2016). The ingredients of HPCs are almost same as those of CCC but because of lower water cement ratio, presence of pozzolans and chemical admixtures etc., the HPCs usually have many features which distinguish them from CCCs. From practical considerations, in concrete constructions, apart from the final strength, the rate of development of strength is also very important. The HPC usually contains both pozzolanic and chemical admixtures. Hence, the rate of hydration of cement and the rate of strength development in HPC is quite different from that of CCC. The proportioning (or mix design) of normal strength concretes is based primarily on the w/c ratio 'law' first proposed by Abrams in 1918. The water/cement (w/c) ratio in the concrete is greater than 0.38 for a normal concrete, whereas it varies between 0.20 and 0.38 for HPC (Bertil, 1998).

It is truly accepted that the concrete will be needed to increase the industrialization and urbanization of a society and protecting the environment simultaneously. To achieve the same, the concrete industry is considering recycling of industrial by-products safely and economically. When industrial by-products, such as fly ash replace cement even up to 70% in concrete, the environmental impact improves, along with energy efficiency and durability of the concrete (Naik et al, 2003). Aggregates being occupying more than 70% of the concrete matrix are considered one of the main constituents of concrete. In many countries there is scarcity of natural aggregates that are suitable for construction while in other countries there is an increase in the consumption of aggregates due to the greater demand by the construction industry. In order to reduce dependence on natural aggregates as the main source of aggregate in concrete, artificially manufactured aggregates and artificial aggregates generated from industrial wastes provide an alternative for the construction industry. Therefore, utilization of aggregates from industrial wastes can be good alternative to the natural aggregate. Without proper alternative aggregates being utilized in the near future, the concrete industry globally will consume 8–12 billion tons annually of natural aggregates after the year 2010 (Tu et al,2006). 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 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. Also, the production of approximately 0.36, 0.244, 2.0, and 4.0 million tons of copper slag is reported in Iran, Brazil, Japan and the United States, respectively. (Khanzadi et al, 2009).

There have been various experiences in using copper slag as a substitute of sand for fine aggregate in high performance concretes. (Al-Jabri et al.,2009) observed that the use of copper slag in HPC is a good option having threefold advantages of eliminating the cost of dumping, reducing the cost of concrete and minimizing air pollution problems. However, there has been little research regarding the incorporation of copper slag as a fine aggregate to produce HPC. Thus this study is focusing to have review on the use of copper slag as sand replacement in the production of high performance concrete.

LITERATURE REVIEW

Fresh Concrete Properties

Due to low water absorption characteristics, workability of HPC was found to increase with the increase in the % of copper slag. It is beneficial for low w/b ratio concretes for the same amount of sand replaced but 100% replacement leads to bleeding and segregation having detrimental effects on concrete performance. For HSC, 75% replacement is acceptable (Madheswaran et al,2014). Maximum slump obtained is 245mm for 100% copper slag as compared to 60mm of the control mix. Addition of copper slag increases the workability due to its smooth glassy surface texture & low moisture absorption (Wu et al, 2010). The workability of concrete increases significantly with the increase of copper slag content in concrete mixes. For the control mixture, the measured slump was 28 mm whereas for mix with 100% replacement of copper slag, the measured slump was 150 mm. (Ayano et al,2000) Substantial increase in the workability of concrete was reported as copper slag content increases. The measured slump for the control mixture with 100% sand was 65.5 mm, while the measured slump for the concrete mixture with 100% copper slag substitution was 200 mm.. However, segregation and bleeding were observed in concrete mixtures with high copper slag contents (Al Jabri et al, 2011).

Mechanical Properties

Compressive strength

Compressive strength after 7,28,90 days curing periods shows decreasing profile as more copper slag is added (Wu et al, 2010) contradicting previous studies of Al Jabri et al, 2009 and Hwang,1989. The test results (Al Jabri et al, 2011) indicate that for mixtures prepared using up to 60% copper slag replacement, the compressive strength of concrete is comparable to the strength of the control mix with 100% sand. However, for mixtures with 80% and 100% copper slag, the compressive strength decreased rapidly below the strength of the control mixture. 19% increase in compressive strength after 7 &28 days is observed as compared to conventional control concrete upto 50% replacement of copper slag (Madheswaran et al. 2014). 40% replacement of copper slag increased around 32.93% of compressive strength as compared to control mix (Brindha et al, 2010). Maximum Compressive strength of concrete increased by 55% at 40% replacement of fine aggregate by copper slag, and up to 75% replacement, concrete gain more strength than control mix concrete strength(Chavan et al. ,2013).

Splitting tensile strength

The 28 days tensile splitting strength generally shows a decreasing profile as more copper slag is added. The decline of the tensile splitting strength is also due to the increasing porosity of the concrete that induced by trapped excess water. The porous internal structure causes the concrete to be prone to failure in tensile cracking at the weak bonds between the concrete components. The effect became more serious in higher copper slag content with increasing porosity, resulting in a drastic drop of tensile splitting strength (Wu et al, 2010). The percentage increase in split tensile strength was found to be 15.2% at 15% replacement of cement and 36.45% at 40% replacement of sand. The combination specimens also give

11.12% higher split tensile strength than that of control concrete. Therefore, it was observed that the addition of copper slag increased the split tensile strength of concrete admixed concrete up to 40% addition in sand and 15% addition in cement (Brindha et al. 2010).

Durability Properties

Chloride penetration

Charge passed for copper slag admixed concrete has shown slightly higher values than control mix concrete but within limits indicating very low permeability. Addition of copper slag definitely reduces the pores of concrete and makes the concrete impermeable (Brindha et al. 2010).   Concrete mixtures containing 8% SF and 25% copper slag appear to have high early strength with superior chloride penetration resistance (Hooton et al. 2004). There was a progressive increase in the resistance to chloride-ion penetration from the normal-strength concrete to the high-strength concrete without silica fume and to the high-strength concrete with silica fume(Chia et al. 2002). As per ASTM C1202, the chloride penetrating value obtained for copper slag admixed concrete is graded under the category “very low”. As such, it is indicating lesser permeability of slag admixture concrete. The important observation is that addition of slag definitely reduces the pores of concrete and makes the concrete impermeable (Brindha et al. 2011).

Sulphate resistance

Upto 40% replacement of sand with copper slag shows higher resistance against sulphate attack (Brindha et al. 2010). High-performance concretes that contain various combinations of silica fume and natural pozzolan can provide good balance between strength and durability, and can be recommended for use in concrete industry. After one-year immersion in sulfates solutions and sea waters, the concrete mix containing a combination of 15% silica fume, and 15% natural pozzolan (by weight of cement) showed a maximum protection against sulfate attack(Shanaag,2004). The application of copper slag waste effectively reduced the deteriorative sulfate expansions as much as replacing of cement by 5%, 10% and 15% of copper slag led to 57.4%, 63.4% and 64.7% lower expansion than that of concrete without copper slag. The copper slag contained concretes showed better compressive strength performance in sulfate comparing with the control concrete specimens. Although the strength of copper slag contained concretes observed to be lower than control concerts in normal condition, they could develop their strength up to or even more than the control concrete mixture in sulfate attack condition(Najimi et al. 2011).

Carbonation

Copper slag concrete had a decrease in advancing carbonation front, 80% and 35.7% for 0.50 and 0.60 w/c ratios, respectively during the exposure of 5% CO_2 concentration. This suggests that copper slag concrete has a lower diffusivity of CO_2 because of the denser structure of the hardened copper slag cement paste when compared to ordinary Portland cement (Moura, 2007).

CONCLUSION

1. Since copper slag concrete exhibits good durability characteristics, it can be used as an alternate to fine aggregate.
2. Copper slag, in the range of 40–50%, could potentially replace sand in concrete mixtures in order to obtain HPC with good properties. With higher levels of replacements (100%)

there was a slight bleeding tendency and it is recommended that up to 80% of copper slag can be used as replacement of sand. The studies show that total replacement of sand by copper slag is not advisable.

3. From this study it may be concluded that the use of copper slag as sand substitution improves strength and durability characteristics.
4. It may be preferable to avoid the use of copper slag as the only fine aggregate in concrete mixes; it may be necessary to add conventional sand (and finer materials such as fly ash and stone dust) also in order to improve the particle size distribution of the concrete mix to get the cohesiveness and satisfactory workability.
5. Very limited research is done on the mechanical and durability properties of high performance concrete with partial substitution of sand with copper slag. So, there is lot of scope to study regarding the same.

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