Mechanical and Durability Properties of RC Beams Using Copper Slag as Fine Aggregate in Concrete

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Abstract - ***In the last few decades there has been rapid increase in the waste materials by-products. Some of the industrial by-products like GGBS, fly ash, silver slag, steel slag, silica fume have been successfully replaced for cement and concrete in the construction industry. It reduces the consumption of natural resources.Copper slag is one of the materials that is considered as a by-product (waste material) obtained during the matte smelting and refining of copper. It has the physical properties similar to the fine aggregate, so it can be used as a replacement for fine aggregate in concrete. By the replacement of 40% of copper slag (by weight) as replacement for fine aggregate. And by the replacement of 20% of fly ash (by weight) as replacement for cement will produce a concrete.***

Key words: *copper slag, fly ash, gfrp.*

1.INTRODUCTION

Aggregates which are used in concrete are obtained either from natural sources or by crushing large size rocks. In order to reduce dependence on natural aggregate in construction, artificially manufactured aggregate and some industrial waste material can be used as an alternative. Since the beginning of the industrial revolution, slag, glassy materials and left over material when metals have been extracted from ores have been considered as waste. And ordinary Portland cement becomes an important material in the production of concrete
Which act as its binder to bind all the aggregate together.However, the utilization of cement causes pollution to the environment and reduction of raw material (limestone). The manufacturing of OPC requires the burning of large quantities of fuel and decomposition of limestone, resulting in significant emissions of carbon dioxide.

Another more recent trend, partially in response to an increased focus on sustainability, is an increase in the utilization of supplementary, is an increase in the utilization of supplementary cementitious materials (SCMs), such as slag, fly ash, and silica fume in concretes. Replacing am portion of the cement with an SCM often reduces early-age strengths and produces de-layed setting times, for mixtures formulated at the same water-to-cementitious materials ratio (w/cm).

2. MATERIALS

2.1 Cement

Cement is a material, generally in powder form, that can be made into paste usually by addition of water. Ordinary Portland cement 53 grade with specific gravity of 3.15 is used for the investigation.

2.2 Fine Aggregate

Naturally available fine aggregate is used for casting the specimens. The fine aggregate was passing through 4.75mm sieve and had

2.3 Coarse Aggregate

Machine crushed angular granite metal of maximum size of 20mm retained on 4.75mm IS sieve confirming to IS 383-1970 was used in the present investigation. It is free from impurities such as dust, clay particles and organic matter etc. The coarse aggregate is also tested for its various properties.

2.4 Copper Slag

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 aggregate. It is a by product obtained during the matte smelting and refining of copper. One of the materials is the copper slag that is produced during mate smelting and converting steps. Therefore, nowadays utilization of secondary materials is being encouraged in construction field. The molten copper slag forms at the bottom of the furnace while molten slag is formed on top. The molten copper slag is then drained off and quenched with water or left in the air to cool.During blasting, copper slag breaks into smaller particles on impact with metal surfaces. After several rounds of reuse, the copper slag gets contaminated with rusts and paints and becomes a waste material but without any change in its chemical composition.

2.5 Fly Ash

Fly ash is residues generated in combustion, and comprises the fine particles that rise with the flue gases. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash.

3. LITERATURE REVIEW

Ambily P.S. [3] et al. (2015) investigated the technical feasibility of using copper slag as fine aggregate replacement in ultra high performance concrete.The studies demonstrated that it is possible to produce UHPC having compressive strength greater than 150 Mpa by incorporation of copper slag. The complete replacement of standard sand by copper slag resulted in a maximum decrease in 28-day compressive strength of about 15–25% whereas, the flexural strength, fracture energy recorded was of the similar order. It can be concluded from the results that use of copper slag as fine aggregate in UHPC is technically viable. The optimum packing density for copper slag obtained in the binary combination of G1 (70%) and G3 (30%).The mean compressive strength of UHPC using the CS and Ennore sand (ES) was 162 Mpa and 191 Mpa, respectively at the age of 28 days.

Zhu et al.[24] (2013) experimentally investigated of the behavior of corroded reinforced concrete beams. These have been stored in a chloride environment for a period of 26 years under service loading so as to be representative of real structural and environmental conditions. The configuration and the widths of the cracks in the two seriously corroded short-span beams were depicted carefully, and then the beams were tested until failure by a three-point loading system. Another two beams of the same age but without corrosion were also tested as control specimens. A short span arrangement was chosen to investigate any effect of a reduction in the area and bond strength of the reinforcement on shear capacity. The relationship of load and deflection was recorded so as to better understand the mechanical behavior of the corroded beams, together with the slip of the tensile bars. The corrosion maps and the loss of area of the tensile bars were also described after having extracted the corroded bars from the concrete beams. Tensile tests of the main longitudinal bars were also carried out. The residual mechanical behavior of the beams is discussed in terms of the experimental results and the cracking maps. The results show that the corrosion of the reinforcement in the beams induced by chloride has a very important effect on the mechanical behavior of the short-span beams, as loss of cross-sectional area and bond strength have a very significant effect on the bending capacity.

Shi et al. [25](2012) have studied the durability of steel reinforced concrete in chloride environments is of great interest to design engineers, infrastructure owners and maintainers, and researchers. This review reports recent advances in the knowledge base relevant to the durability of steel reinforced concrete in chloride environments, including: the role of mineral admixtures in concrete durability, the methods of measuring the chloride ingress into concrete, the challenges in assessing concrete durability from its chloride diffusivity, and the service life modeling of reinforced concrete in chloride-laden environments. Existing chloride permeability tests are either very time-consuming for high quality concrete mixes or too biased to provide reliable chloride diffusion coefficients.

Brindha D et al.[6] (2011) experimentally studied the various corrosion and durability tests on concrete containing copper slag as partial replacement of sand and cement. For this research work, M20 grade concrete was used and the tests were conducted for various proportions of copper slag replacement with sand of 0 to 60%, cement of 0 to 20% in concrete. The test to be conducted on compressive strength, split tensile strength, ultrasonic pulse velocity, accelerated corrosion, rapid chloride permeability test. The obtained results were compared with those of control concrete made with ordinary Portland cement and sand. Replacement of copper slag in bothfine aggregate and cement replacement reduces the cost of making concrete. The results of compressive,split tensile strength test have indicated that the strength of concrete increases with respect to the percentage of slag added by weight of fine aggregate up to 40% of additions and 15% of cement.

Sudarvizhi et al. [15] (2011) have reported an experimental procedure to investigate the effect of using copper slag and ferrous slag as partial replacement of sand. The strength characteristics of conventional concrete and slag concrete such as compressive strength, tensile strength were found.Six series of concrete mixtures were prepared with different proportions of cs and fs ranging from 0%to100%. The test results of concrete were obtained by adding CS and FS to sand in various percentages ranging from 0%, 20%, 40%, 60%, 80% and100%. The results indicate that workability increases with increase in CS and FS percentage. The highest compressive strength obtained was 46 Mpa and the corresponding strength for control mix was 30 Mpa.it has been observed that upto 80% replacement, CS and FS can be effectively used as replacement for fine aggregate. Further research work is needed to explore the effect of CS.

Najimi M et al.[17] (2011) explained about the article, the performance of copper slag contained concrete in sulfate solution is investigated.In this regard, an experimental study including expansion measurements, compressive strength degradation and micro structural analysis were conducted in sulfate solution on concretes made by replacing 0%,5%,10% and 15% of cement with copper slag waste.The result of this study emphasized the effectiveness of copper slag replacement in improving the concrete resistance against sulfate attack. In this study, the sulfate resistance of concrete made with 5%, 10% and 15% of copper slag were studied in comparison with concretes without copper slag replacement.

Nath P. et al.[18] (2011) had studied the Utilization of fly ash as a supplementary cementitious material adds sustainability to concrete by reducing the CO2 emission of cement production. The positive effects of fly ash as a partial replacement of cement on the durability of concrete are recognized through numerous researches; however, the extent of improvement depends on the properties of flyaz ash. In this study, durability properties of high strength concrete utilizing high volume Class F fly ash sourced from Western Australia have been investigated. Concrete mixtures with fly ash as 30% and 40% of total binder were used to cast the test specimens. The compressive strength, drying shrinkage, Sorptivity and rapid chloride permeability of the fly ash and control concrete specimens were determined. The 28-day compressive strength of the concrete mixtures varied from 65 to 85 Mpa. The fly ash concrete samples showed less drying shrinkage than the control concrete samples when designed for the same 28-day compressive strength of the control concrete. Inclusion of fly ash reduced Sorptivity and chloride ion permeation significantly at 28 days and reduced further at 6 months. In general, incorporation of fly ash as partial replacement of cement improved the durability properties of concrete.

Brindha D et al.[7] (2010) suggested in the results of an experimental study on various corrosion and durability tests on concrete containing copper slag as partial replacement of sand and cement.For this research work, M20 grade concrete was used and the tests were conducted for various proportions of copper slag replacement with sand of 0%,20%,40% and 60%,cement of 0%,5%,15% and 20% in concrete.The obtained result were compared with those of control concrete made with ordinary portland cement and sand. Water permeability in concrete reduced up to 40% replacement of copper slag with that of sand. That addition of slag definitely reduces the pores of concrete and makes the concrete impermeable. The addition of copper slag for the replacement of sand shows higher resistance against sulphate attack. Since copper slag concrete exhibits good durability characteristics,it can be used as an alternate to fine aggregate and also be utilized in cement as a raw material for making blended cements.

Wu et al.[23] (2010) have studied the dynamic compressive strength of the copper slag reinforcement concrete (CSRC) is generally improved, compared with the control concrete, with the increase of copper slag replacement up to 20%, due to the excellent physical and mechanical properties of copper slag. The dynamic compressive strength of the CSRC with 40% substitution amounts of copper slag is closed to that of control concrete and beyond which the strength generally reduces. With the increasing content of sand replacement with copper slag, there appears to be a higher content of voids, micro cracks and capillary channels in CSRC than in the control concrete, especially when the substitution rate exceed 20% which may be mainly attributed to the presence of excess water and results in deterioration of concrete quality.

Pazhani k et al. [20] (2010) suggested replacing some percentage of fine aggregate with copper slag and some percentage of cement with GGBS to develop high performance concrete. This paper presents an experimental investigation to asses the durability parameters of high performance concrete with the industrial wastes. Durability parameters such as water absorption and chloride penetration are to be studied. The water absorption for 30% replacement of cement with GGBS decreases by 4.58%. Also, the water absorption for 100% replacement of fine aggregate with copper slag decreases by 33.59%. The chloride ion penetrability for 30% replacement of cement with GGBS decreases by 29.90. Also, the 100% replacement of fine aggregate with copper slag decreases by 77.32%.

Al-jabri S. et al.[12] (2009) investigated the effect of using copper slag as a replacement of sand on the properties of high performance concrete.Eight concrete mixtures were prepared with different proportions of copper slag ranging from 0%(for a control mix) to 100%.Concrete mixes were evaluated for workability,density,compressive strength,tensile strength, flexural strength and durability.The results indicate that there is a slight increase in the HPC density of nearly 5% with the increase of copper slag content,where as the workability increased rapidly with increases in copper slag percentage.The result also demonstrated that the surface water absorption decreased as copper slag quantity increases up to 40% replacement; beyond that level of replacement, the absorption rate increases rapidly. The surface water absorption of concrete was reduced with up to 40% copper slag replacement for sand.

Alnuaimi et al. [2] (2009) have studied the use of copper slag as a replacement for fine aggregate is investigated. Three slender reinforced concrete columns of 150x150x2500mm were tested for monotonic axial compression load until failure. The ratios of copper slag to fine aggregate were 0%, 40%and 80%. Four -8mm diameter high yield steel bars were used as longitudinal reinforcement and 6mm diameter mild steel bars were used as stirrups. Three cubes, 100x100x100mm, three cylinders, 150x300mm, and three prisms, 100x100x500mm, were cast from the same mix of each specimen at the same time.The test results so far showed that up to 40% replacement of fine aggregate by copper slag does not have a significant effect on the load carrying capacity of the columns.The results collected so far showed that increasing the ratio of copper slag as a replacement for fine aggregate reduces the column failure load and increasing deflection.

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Mostafa khanzadi et al. [16] (2009) investigated the feasibility of using copper slag as coarse aggregates in high strength concrete. Concrete mixtures containing different levels of silica fume were prepared with water to cementitious materials ratios of 0.40, 0.35, and 0.30. The percentages of the cement replacements by silica fume were 0%, 6%, and 10%. The stronger bonding between copper slag aggregate and the cement paste matrix. Compressive strengths increased from 11% to 14%, whereas the splitting tensile strength showed an increase between 13% and 15%. The larger splitting tensile strength increases show that it is more sensitive to aggregate surface textures than compressive strength. The improvement in the mechanical properties of concretes incorporating copper slag indicates that copper slag, a waste by-product of the copper industry, can be used beneficially as coarse aggregate for high strength concrete.

Al-jabri et al.[12] (2009) have presented the performance of high strength concrete made with copper slag as a fine aggregate at constant workability and to study the effect of super plasticizer addition on the properties of HSC made with copper slag. The absence of the super plasticizer from the concrete mixtures made with copper slag caused significant reduction in the strength of HSC and increased substantially the absorption of concrete due to the segregation and dryness of concrete paste in all mixtures. It concluded that the use of copper slag as sand substitution improves HSC strength and durability characteristics at same workability while super plasticizer is very important ingredient in HSC in order to provide good workability and consistency for the concrete matrix and produce HSC that meets strength and durability design requirements.

Apostolopoulos C.A. et al. [4] (2008) the main corrosion initiation mechanisms were shortly presented. Further, the propagation period and the main consequences on mechanical properties of steel and concrete are analyzed. The experimental results show that with increasing duration of exposure to a corrosive environment, the steel mass loss increases appreciably. This leads to a significant increase of the applied stress. In addition, a significant reduction of the tensile ductility of the material was observed. For laboratory salt spray exposure periods, some of the tensile properties of steel bars drop to values lying below the limits, which are set in the existing standards for using steels in reinforced concrete members. The experimental results from the accelerated corrosion tests on bare steel bars are in a good qualitative agreement with results from steel bars embedded in aged concrete.

Shi et al. [8](2008) have studied the use of copper slag in cement and concrete provides potential environmental as well as economic benefits for all related industries, particularly in areas where a considerable amound of copper slag is produced. This paper reviews the characteristics of copper slag and its effects on the engineering properties of cement, mortars and concrete.Also more amounts of copper slag will be utilized by using it as fine and coarse aggregates in concrete because more than 70% of concrete volume is occupied by aggregates.The review of the results of other works which were presented in this paper encourages increasing the rate of reuse and recycling of properly prepared copper slag.

Dinakar P.et al. [10] (2008) experimentally studied the durability properties of self compacting concretes with high volume replacements of fly ash. Eight fly ash self compacting concretes of various strength grades were designed at desired fly ash percentages of 0, 10, 30, 50, 70 and 85%, in comparison with five different mixtures of normal vibrated concretes at equivalent strength grades. The durability properties were studied through the measurement of permeable voids, water absorption, acid attack and chloride permeation. The results indicated that the SCCs showed higher permeable void sand water absorption than the vibrated normal concretes of the same strength grades. However, in acid attack and chloride diffusion studies the high volume fly ash SCCs had significantly lower weight losses and chloride ion diffusion.

Vidal T. et al. [22] (2007) studied the long-term corrosion process of reinforced concrete beams. The reinforced concrete elements were stored in a chloride environment for 17years under service loading in order to be representative of real structural conditions. At different stages, cracking maps were drawn, total chloride contents were measured and mechanical tests were performed. Results show that the bending cracks and their width do not influence significantly the service life of the structure. The chloride threshold at the reinforcement depth, used by standards as a single parameter to predict the end of the initiation period, is a necessary but not a sufficient parameter to define service life. The steel–concrete interface condition is also a determinant parameter. The bleeding of concrete is an important cause of interface de-bonding which leads to an early corrosion propagation of the reinforcements. The structural performance under service load is mostly affected by the corrosion of the tension reinforcement. Limit-state service life design based on structural performance reduction in terms of serviceability shows that the propagation period of the corrosion process is an important part of the reinforced concrete service life.

Al –jabri et al. [1] (2006) have studied the effect of copper slag and cement by-pass dust addition on concrete properties. In addition to the control mixture, two different trial mixtures were prepared using different proportions of CS and CBPD. CBPD was primarily used as an activator. One mixture consisted of 5% copper slag substitution for Portland cement. The other mixture consisted of 13.5% CS, 1.5% CBPD and 85% Portland cement. Three water-to-binder (w/b) ratios were studied: 0.5, 0.6 and 0.7. Concrete cubes, cylinders and prisms were prepared and tested for strength after 7 and 28 days of curing. The modulus of elasticity of these mixtures was also evaluated. The results indicate that the use of 5% copper slag in lieu of Portland cement would yield a similar performance as the control mixture, especially at low water- to-binder ratios of 0.5 and 0.6. Higher copper slag (13.5%) replacement for cement resulted in adverse effects on concrete strength. This is expected since copper slag has a low free lime content of 6% compared with 63% free lime in Portland cement.

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Berke et al. [19] (2004) presented that the levels of chloride to which given levels of calcium nitrite will protect. Furthermore, it will be shown that once corrosion initiates, the rates are lower with calcium nitrite present. Finally, it is demonstrated how these results can be used by the design engineer in an integrated durability model to produce reinforced concrete structures with durability in excess of 50–100 years. Corrosion rate data on laboratory specimens are in good agreement with autopsy results, but are not a substitute for verification by autopsy.

Gorai et al.[5] (2003) have presented this paper gives a review of characteristics of copper slag as well as various processes such as pyro,hydro and combination of pyro-hydrometallurgical methods for metal recovery and preparation of value added products from copper slag. Favourable physico-mechanical and chemical characteristics of copper slag lead to its utilisation to prepare various value added products such as cement,fill,ballast.abrasive,cutting tools,aggregate,roofing granules,glass,tiles etc. these materials have been found to be possessing superior mechanical properties and they may be of cheaper varieties than the similar conventional materials.

Shi et al.[9] (2000) reviewed the recent achievements in the development of high performance cementing materials based on activated slags such as blast furnace slag , steel slag, copper slag and phosphorus slag and the recent progresses in the activation of latent cementitious properties of different slags. Alkali –activated slags , such as blast furnace slag ,steel slag , copper slag and phosphorus slag exhibit not only higher early and later strength , but also better corrosion resistance than normal portland cement.

Tixier R et al. [21] (1997) have presented the effect of copper slag on the hydration of cement-based materials is studied. Up to 15% by weight of copper slag was used as a Portland cement replacement. Hydration reactions were studied through semiquantitative X-ray diffractive and TGA/DTA.copper slag is shown to significantly increase the compressive strength of concrete mixtures. XRD results of slag lime samples indicate a clear decrease in the available CH content. This observation however was not clearly verified in the slag cement mixtures.

Goni et al.[11] (1994) have investigated the reactivity of hydrated Portland cement pastes containing up to a 30% of a Spanish ground copper slag in an aggressive solution has been studied in order to evaluate the changes in microstructural and mechanical properties of the composite. Flexural strength data were related to microstructural parameters, studied by means of X-ray diffraction as well as porosity and pore-size distribution analyses. These processes decrease the porosity of the materials, thus increasing their flexural strengths.

4. CONCLUSION

From the journals, it is concluded that copper slag can be effectively used as replacement material for fine aggregate and replacement enables the large utilization of waste product.Copper slag has lower absorption and higher strength properties than fine aggregate.Replacement of copper slag increases the self weight of concrete specimens to the maximum of 15% to 20%. The addition of GFRP wrapping in RC beams increases the load carrying capacity and reduction in deflection

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