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Experimental Investigation on Use of Copper Slag and Recycled Aggregate as a Fine Aggregate in Concrete

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Abstract: ***Conservation of natural resources and preservation of environment is the essence of any modern development. In last few decades, construction activities increase rapidly. Itsss require more raw materials and it will result in shortage of material in future. Now a days there is trend of recycling and reusing material, which is partial solution of this problem. Also, Industrial wastes are used as raw material. It reduces the consumption of natural resources. Copper slag and recycled aggregate are the industrial waste and recycled material used as a fine aggregate in concrete. Both the material has same physical properties similar to the fine aggregate. By replacing 10% to 50% copper slag as fine aggregate, concrete produced. At the optimum content of copper slag, 10% to 50%of recycled aggregate replaced and the concrete produced.***
Key words: copper slag, recycled aggregate.

I. 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. Also, aggregates are considered as inert material therefore it can be easily replaced in comparison of any other constituent of concrete. Use of copper slag and recycled aggregate as a fine aggregate in concrete reduce amount of natural aggregate in concrete and also useful in waste management.

Avikal Somvanshi, Senior Research Associate, Sustainable Buildings and Habitat Programme, CSE, reported that, in 2013, Indian buildings generated over 530 million tonnes of concrete debris, which is a very huge amount. It required considerable space for dumping. In other hand, copper slag is industrial waste produced during process of smelting. It produced in amount of 24.5 million tonnes per annum, Gorai (2013). As both the materials in huge amount, its use in concrete can cover the problem at such extent.

A. 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.

B. Recycled Aggregate

Large quantities of crushed concrete produced in India and elsewhere in the world. Owing to the increasing cost of landfill, the scarcity of natural resources coupled with the increase in aggregate requirement for construction, the use of recycled aggregate to partially replace the virgin aggregate has, therefore, become more common.

There have been a number of publications on the use of recycled aggregate in concrete. It was concluded that concrete strength decreases when recycled concrete was used and the strength reduction could be as low as 40%. However, no decrease in strength was reported for concrete containing up 20% fine or 30% coarse recycled concrete aggregates, but beyond these levels, there was a

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systematic decrease in strength as the content of recycled aggregates increased.

II. LITERATURE REVIEW

Alnuaimi[2] (2012), discussed the possibility to replace virgin fine aggregate with copper slag in structural concrete. As aggregate is the main constituent of concrete, occupying more than 70% of the concrete matrix. In order to reduce depletion of natural aggregate due to construction, artificially manufactured aggregate and some industrial waste materials can be used as alternatives. Author stated Copper slag (CS), the glassy material, produced during matte smelting and copper conversion was previously considered waste and disposed as landfill. It has been estimated that for every ton of copper production about 2.2-3 tons of slag are generated. In this research paper, Use of copper slag (CS) as a replacement for fine aggregate (FA) in RC slender columns was experimentally investigated in this study. Author performed tests to determine basic properties of concrete and also determine lateral deflection and vertical deflection for the RC column made by copper slag concrete. Author kept contents of cement, water, and coarse aggregate were constant while the percentages of CS as a replacement for FA varied from 0 to 100%.The Results showed that replacement of up to 40% of FA with CS caused no major changes in column failure load, EI or concrete strength.

Khalifa S. Al-Jabri et al.[12] (2010), An experimental investigation was conducted to study the effect of using copper slag as a fine aggregate on the properties of cement mortars and concrete by them. 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. Also, there was more than 70% improvement in the compressive strength of mortars with 50% copper slag substitution in comparison with the control mixture. The results obtained for concrete indicated that there is a slight increase in density of nearly 5% as copper slag content increases, whereas the workability increased significantly as copper slag percentage increased compared with the control mixture. A substitution of up to 40–50% copper slag as a sand replacement yielded comparable strength to that of the control mixture. However, addition of more copper slag resulted in strength reduction due to the increase in the free water content in the mix. Also, the results demonstrated that surface water absorption decreased as copper slag content increases up to 50% replacement. Beyond that, the absorption rate increased rapidly and the percentage volume of the permeable voids was comparable to the control mixture.

M. V. Patil[16] **(**2014), described the introduction and production of copper slag and its various applications in construction industry. In this paper, the author aimed at the greatest potential applications for using copper slag is in concrete production. This research work by author is concerned with the experimental investigation on strength of concrete and optimum percentage of the partial replacement by replacing fine aggregate via 0%, 10%, 20%, 30%, 40% of copper slag. In this paper, properties of copper slag concrete and its comparison with the conventional concrete are also mentioned. Future recommendations about copper slag concrete are also included.

Obinna Onuaguluchi et al.[18] (2012), 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 resultss 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.

D. Brindha et al.[9] (2012), 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 both fine 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.

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Binaya Patnaik et al.[5] (2012), An experiment was conducted to investigate the strength and durability properties of concrete having copper slag as a partial replacement of sand (fine aggregate) and results have been presented in this paper by authors. Two different types of Concrete Grade (M20 & M30) were used with different proportions of copper slag replacement (0 to 50%) in the concrete. Strength & Durability properties such as Compressive Strength, Split Tensile Strength, Flexural Strength, Acid Resistivity and Sulphate Resistivity were evaluated for both mixes of concrete. Test results shows that the strength properties of concrete has improved having copper slag as a partial replacement of Sand (upto 40%) in concrete however in terms of durability the concrete found to be low resistant to acid attack and higher resistance against Sulphate attack.

C.K. Madheswaran et al.[7] (2012), This paper focuses on the use of copper slag, as a partial replacement of sand for use in cement concrete and building construction. Cement mortar mixtures prepared with fine aggregate made up of different proportions of copper slag and sand were tested for use as masonry mortars and plastering. The studies showed that although copper slag based mortar is suitable for plastering, with the increase in copper slag content, the wastage due to material rebounding from the plastered surfaces increases. The authors suggested that the copper slag can be used for plastering of floorings and horizontal up to 50 % by mass of the fine aggregate, and for vertical surfaces, such as, brick/block walls it can be used up to 25 %. In this study on concrete mixtures were prepared with two water cement ratios and different proportions of copper slag ranging from 0 % (for the control mix) to 100 % of fine aggregate. The Concrete mixes were evaluated for workability, density, and compressive strength.

M. Najimi et al.[14] (2012), Sulphate attack is one of several chemical mechanisms of concrete deterioration. Exposure of concrete structures in the sulphate environments may lead to detrimental chemical, micro-structural, and physical changes in the concrete matrix, resulting in serious deteriorations and service life reduction. Partial replacement of cement with slag is one of the efficient methods for improving concrete resistance against sulphate attack. In this paper the performance of copper slag contained concrete in sulphate solution is investigated. In this regard, an experimental study including expansion measurements, compressive strength degradation and micro-structural analysis were conducted in sulphate solution on concretes 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.

R R Chavan et al.[21] (2012), reported on an experimental program to investigate the effect of using copper slag as a replacement of fine aggregate on the strength properties. Copper slag is the waste material of matte smelting and refining of copper such that each ton of copper generates approximately 2.5 tons of copper slag. Copper slag is one of the materials that is considered as a waste which could have a promising future in construction Industry as partial or full substitute of aggregates. In this research work, M25 grade concrete was used and tests were conducted for various proportions of copper slag replacement with sand of 0 to 100% in concrete. The obtained results were compared with those of control concrete made with ordinary Portland cement and sand.

Parekh D.N et al.[19] (2011), reported the basic properties of recycled fine aggregate and recycled coarse aggregate. They also compared these properties with fresh aggregates. Basic changes in all aggregates properties were determined and their effects on concreting work were discussed by them. They determined and explained the properties of recycled aggregate concrete. In this paper, they explained different concrete properties like compressive strength, flexural strength, workability etc for different combinations of recycled aggregates with natural aggregates. They stated that, in general recycled concrete aggregate in India with their future need and its successful utilization.

C. Thomas et al.[8] (2012), presented the main results of the research carried out to analyze the technical feasibility of concrete incorporating recycled concrete aggregate from crushed tested concrete cubes. Their main objective is to demonstrate that procedures of concrete waste from tested cubes can use this waste for recycled concrete aggregate despite the presence of sulphur. The presence of sulphur in the recycled concrete aggregates thus obtained may have effect on properties of the concrete. In this experiment, a characterization program of recycled aggregate concrete without sulphur has been undertaken. Authors concluded that the use of recycled aggregate concrete, with or without sulphur, is useful for the manufacture of recycled structural concrete. However, the use of fine fraction means a significant loss of properties.

Ashraf M. Wagih et al.[3] (2012), discussed possibility to replace virgin coarse aggregate with recycled concrete aggregate in structural concrete. An investigation into the properties of recycled concrete aggregate is made using crushing and grading of concrete rubble collected from different demolition sites and landfill locations around cairo was done by the authors. Aggregates used by them were natural sand, dolomite and crushed concrete obtained from different sources. A total of 50 concrete mixes forming eight groups were cast by them. They designed groups to study the effect of recycled coarse aggregate quality, content, cement dosage, use of super plasticizer and silica fume. They carried out tests like compressive strength, splitting strength and elastic modulus. The results obtained by them showed that the concrete rubble could be transformed into useful recycled concrete

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aggregate and used in concrete production with properties suitable for most structural concrete applications in Egypt. The authors observed significant reduction in the properties of recycled aggregate concrete (RAC) made of 100% RCA was seen when compared to virgin aggregate concrete, while the properties of the recycled aggregate concrete made of a blend of 75% virgin aggregates showed no significant change in concrete properties.

Akira Shintani et al.[1] (2014), gave the advantages of recycled concrete aggregate is a promising technology for resource saving and low environmental impacts, which is more effectively performed when recycled fine aggregates are used n addition to recycled coarse aggregate. Authors showed the use of recycled fine aggregates for the upper structure, shows minor progress because low in aggregate quality and emission of fine particles. Two effective technologies, production of energy saving mid-quality recycled concrete aggregate and high-quality recycled fine aggregate, presented by authors enabled the application of mid quality recycled concrete aggregate to the upper structure for the first time in Japan.

Benito Mas et al.[4] (2011), presented the results of an experimental program on the influence of replacing virgin aggregate with mixed recycled concrete aggregate in the mix design of non-structural concrete. A mix design suitable for manufacturing low strength blinding concrete (15 MPa), medium strength blinding backfill concrete (25 MPa) and non structural concrete for high resistance precast element (65 MPa) is proposed by authors. According to the properties of mixed recycled aggregates, the conclusion drawn by the authors was that it is feasible to substitute about 40% of coarse aggregate in such a way that the resulting coarse aggregate mix complies with all regulatory requirement analyzed. The higher absorption capacity of mixed recycled concrete aggregates means that special care in the mix design required because consistency may be affected. In a hardened state, the compressive, tensile and flexural strength properties decreased when the proportion of mixed recycled aggregate increases shown by the authors. This decrease is higher when the concrete's average compressive strength increases. At 90 days, the reduction in average compressive strength is less than 15% for replacement around 20% of the coarse aggregate.

III. CONCLUSION

From the above research papers, it is concluded that copper slag and recycled aggregates 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. In other hand replacement of fine aggregate by recycled aggregate also effective. By increasing amount of RA, the strength decrease. Therefore it is advisable to replace FA by RA at limited extent. Replacement of copper slag increases the self weight of concrete specimens to the maximum of 30% to 40% and replacement of RA of 15% to 20% does not decrease the strength of concrete.

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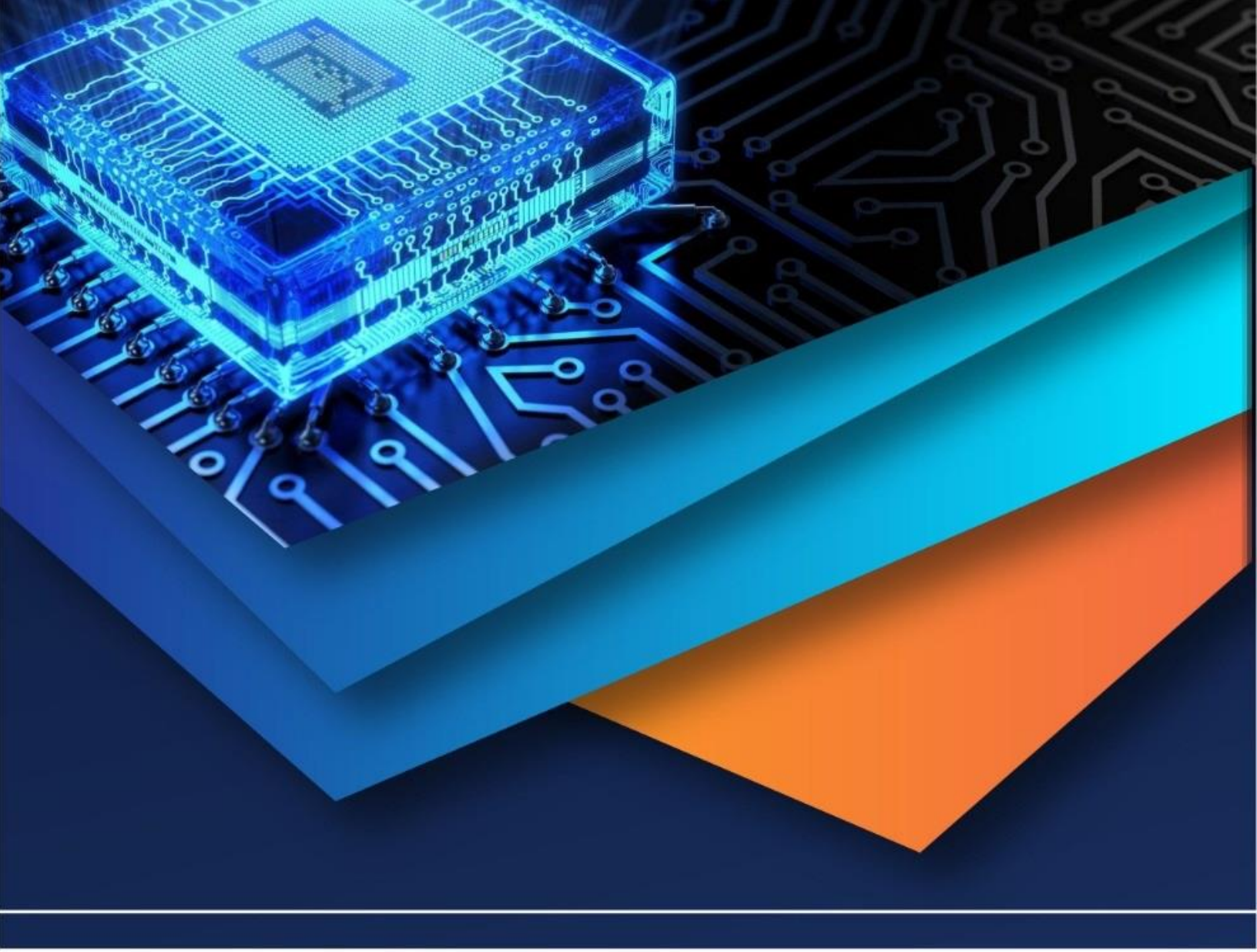
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