A Comparative Study on Mechanical Properties of Concrete by using Copper Slag & Granite Powder as Partial Replacement for Fine Aggregate

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Abstract

Concrete is the most popular building material in the world. It is the most consumable material after water. Concrete is a mixer of binding material, fine aggregate, coarse aggregate and water. Generally Ordinary Portland Cement (OPC) is used as a binding material, Hard Broken Granite (HBG) stone is used as a coarse aggregate and River sand has been the most popular choice for the fine aggregate component of concrete in the past, but overuse of these materials has led to environmental concerns, the depleting of securable Natural resource deposits and a concomitant price increase in the material. As environmental and cost concerns Industrial waste or industrial by products can be used as a partial or full replacement of natural resources. The present, study concerns with the partial replacement of fine aggregate in conventional concrete. The reduction in the sources of natural sand and the requirement for reduction in the cost of concrete production has resulted in the increased need to identify substitute material to sand as fine aggregates in the production of concrete. Various type of materials can be used for replacement in fine aggregate. In which, some of the materials are Copper slag, Granite powder, Granulated blast furnace slag, Washed bottom ash, Quarry dust, Foundry sand, Spent fire bricks, Sheet glass powder, Construction and demolition waste, etc. In present study copper slag and granite powder can be used as a partial replacement of sand. Granite stone powder, a by-product from the cutting process of granite stone used for flooring is one of such materials. Copper slag is a by-product obtained during the matte smelting and refining of copper. The reduction in waste generation by manufacturing value-added products from the granite stone waste will boost up the economy of the granite stone industry. The utilization of granite powder and copper slag in high performance concrete could turn this waste material into a valuable resource with the added benefit of preserving environment. At the same time Copper slag possesses mechanical and chemical characteristics that qualify the material to be used in concrete as a partial replacement or as a substitute for fine aggregates since it is available in large quantity from the world copper industry. In recent days there were also been many attempts to use Fly Ash, an industrial by product as partial replacement for cement to have higher workability, long term strength and to make the concrete more economically available. Here it was attempted the use of Pozzolana Portland Cement (PPC) instead of Ordinary Portland Cement (OPC). This present work is also an attempt to use Granite powder and Copper slag as partial replacement for Sand in M25 grade concrete. Attempts have been made to study the properties of concrete and some properties of Granite powder and Copper slag, their suitability of those properties to enable them to be used as partial replacement materials for sand in concrete.
Keywords: Portland cement, concrete, rice hush Ash (RHA), Specimen Preparation, Testing

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I. INTRODUCTION

Concrete is a non-homogeneous material. It consists of cement, sand and mixed with water. The cement and water form a paste or gel which coats the sand and aggregate. When the cement has chemically reacted with the water (hydrated), it hardens and binds the whole mix together. The initial hardening reaction usually occurs within a few hours. It takes some weeks for concrete to reach full hardness and strength.

Aggregate is the important constituent in concrete. They give body to the concrete, reduce shrinkage and effect economy. Aggregate is a broad category of coarse particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. Aggregates are the most mined materials in the world. Aggregate serves as reinforcement to add strength to the overall composite material. Aggregates are divided into two categories from the consideration of size (i) coarse aggregate and (ii) fine aggregate. The size of aggregate is bigger than 4.75mm is considered as coarse aggregate and whose size is 4.75mm and less is considered as fine aggregate. Hard Broken Granite stone is most commonly used coarse aggregate material and river sand can be used as fine aggregate material in conventional concrete.

II. LITERATURE REVIEW

A. *Literature Review on Copper Slag:*

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.

R R Chavan & D B Kulkarni (2013) [17] 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.

Al-Jabri et al (2011)[1]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 upto 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.

Wei wu et al (2010) [24] 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 increases 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.

Mostafa Khanzadi and Ali Behnood (2009) [15] 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.

Caijun Shi et al (2008) [9] 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.

Shanmuganathan et al., (2007) [19] 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.

Washington Almeida Moura et al (2007) [23] 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.

Byung Sik Chun et al (2005) [8] 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.

Shirule P.A et al (2012) [20] determined the compressive strength and split tensile strength of concrete in which cement was partially replaced with marble dust powder (0%,5%,10%,15%, 20%).The result indicated that the Compressive strength of concrete increased with addition of waste marble powder up to 10% replaced by weight of cement and further addition of waste marble powder was found to decrease the compressive strength. The optimal percentage replacement was found to be 10%.

Baboo Rai et al (2011) [4] investigated the effect of using marble powder and granules as constituents of fines in concrete by partially reducing quantities of cement as well as other conventional fines. The values of workability, compressive strength and flexural strengths were found. Partial replacement of cement and usual fine aggregates with varying percentage of marble powder (0%,5%,10%,15%,20%) and marble granules revealed that increased waste marble powder (WMP) or waste marble granule (WMG) resulted in increase in workability and compressive strength of mortar concrete.

Bouziani Tayeb et al (2011) [7] studied the effect of marble powder content (MP) on the properties self-compacting sand concrete (SCSC) at fresh and hardened states. Values of slump flow, the V-funnel flow time and viscosity were found on fresh concrete. At the hardened state, the 28th day compressive strength was found. The obtained test results showed that larger MP content in SCSC (350 kg/m3) improved the properties at fresh state by decreasing V funnel flow time (from 5s 1.5s) and increasing the slump flow values (from 28cm to 34cm). With the use of 250 kg/m3 of MP, the highest initial viscosity was obtained while retaining good fluidity at high rotational speeds compared to the MP contents of 150 kg/m3 and 350 kg/m3. The 28 days compressive strength decreased with an increase of MP content.

Bahar Demirel (2010) [5] investigated the effects of using waste marble dust (WMD) as a fine material on the mechanical properties of the concrete. For this purpose, four different series of concrete-mixtures were prepared by replacing the fine sand (passing 0.25 mm sieve) with WMD at proportions of 0, 25, 50 and 100% by weight. In order to determine the effect of the WMD on the compressive strength with respect to the curing age, compressive strengths of the samples were recorded at the curing ages of 3, 7, 28 and 90 days. In addition, the porosity values, ultrasonic pulse velocity (UPV), dynamic modulus of elasticity and the unit weights of concrete were determined. It was observed that replacement of the fine material passing through a 0.25mm sieve with WMD at particular proportion has displayed an enhancing effect on compressive strength.

Felixkala.T and Partheeban.P (2010) [10] examined the possibility of using granite powder as replacement of sand along with partial replacement of cement with fly ash, silica fume and blast furnace slag. They reported that granite powder of marginal quantity as partial replacement to sand had beneficial effect on the mechanical properties such as compressive strength, split tensile strength and modulus of elasticity. They also reported that the values of plastic and drying shrinkage of concrete with granite powder were less than those of ordinary concrete specimens.

B. Compressive Strength Studies:

For Compressive strength test standard cube size of 150mm x 150mm x 150mm are used. An average of three specimens are taken for all mixes after a curing period of 7 days & 28 days.

Table – 1
Mean Compressive strength of M25 grade concrete

Mix Designation	*Cement used PPC*	*Fine Aggregate used*	*Percentage replacement in Fine Aggregate*		*Coarse aggregate used*	*Compressive Strength at 7 days N/mm²*	*Compressive strength at 28 days N/mm²*
			Copper slag	*Granite powder*			
M0	*100%*	*100%*	*-----*	*-----*	*100%*	*15.22*	*31.80*
MC15	*100%*	*85%*	*15%*	*-----*	*100%*	*14.56*	*31.75*
MC30	*100%*	*70%*	*30%*	*-----*	*100%*	*15.63*	*32.04*
MC40	*100%*	*60%*	*40%*	*-----*	*100%*	*16.06*	*32.78*
MG15	*100%*	*85%*	*-----*	*15%*	*100%*	*15.04*	*28.65*
MG30	*100%*	*70%*	*-----*	*30%*	*100%*	*15.48*	*31.96*
MG40	*100%*	*60%*	*-----*	*40%*	*100%*	*15.96*	*32.25*
MCG30	*100%*	*70%*	*15%*	*15%*	*100%*	*15.84*	*24.85*
MCG60	*100%*	*40%*	*30%*	*30%*	*100%*	*15.71*	*30.08*
MCG80	*100%*	*20%*	*40%*	*40%*	*100%*	*18.10*	*33.43*

Table – 2
Mean Flexural strength of M25 grade concrete

Mix Designation	*Cement used PPC*	*Fine Aggregate used*	*Percentage replacement in Fine Aggregate*		*Coarse aggregate used*	*Flexural strength at 28 days N/mm²*
			Copper slag	*Granite powder*		
M0	*100%*	*100%*	*-----*	*-----*	*100%*	*4.01*
MC15	*100%*	*85%*	*15%*	*-----*	*100%*	*4.08*
MC30	*100%*	*70%*	*30%*	*-----*	*100%*	*4.14*
MC40	*100%*	*60%*	*40%*	*-----*	*100%*	*4.20*
MG15	*100%*	*85%*	*-----*	*15%*	*100%*	*3.96*
MG30	*100%*	*70%*	*-----*	*30%*	*100%*	*3.86*
MG40	*100%*	*60%*	*-----*	*40%*	*100%*	*4.24*
MCG30	*100%*	*70%*	*15%*	*15%*	*100%*	*6.89*
MCG60	*100%*	*40%*	*30%*	*30%*	*100%*	*6.50*
MCG80	*100%*	*20%*	*40%*	*40%*	*100%*	*6.17*

III. CONCLUSIONS

- Maximum Compressive strength of concrete increased by 3.08% at 40% replacement of fine aggregate by copper slag, and up to 40% replacement, concrete gain more strength than control mix concrete strength, except 15% replacement copper slag concrete.
- It is observed that for all percentage replacement of fine aggregate by Copper slag the flexural strength of concrete is more than control mix.
- It is observed that, the flexural strength of concrete at 28 days is higher than design mix (Without replacement) for 15% replacement of fine aggregate by Copper slag, the flexural strength of concrete is increased by 1.74%. This also indicates flexural strength is more for all percentage replacements than design mix. However, for 40% replacement of fine aggregate by Copper slag concrete gives the maximum strength than control mix.
- Compressive strength and flexural Strength is increased due to high toughness of Copper slag.
- The compressive strength has increased by 1.41% with the use of 40% replacement of fine aggregates with granite powder. Concrete gain more strength than control mix concrete strength, except 15% replacement of granite powder concrete
- It is observed that, the flexural strength of concrete at 28 days is higher than design mix (Without replacement) for 40% replacement of fine aggregate by Granite powder, the flexural strength of concrete is increased by 5.73%. It shows that 40% replacement of granite powder gives the maximum flexural strength, than remaining percentage replacements.

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