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Microstructure study on cement mortar using green sand and copper slag – A review

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Abstract— This paper deals micro structure of cement mortar with green sand and copper slag as replacement of fine aggregate. The replacement of green sand and copper slag will be gradually from 10%, 20%, and 30% by the weight of fine aggregate. The setting time of fresh cement-binder paste and compressive strength of mortar cubes, Scanning electron microscopy (SEM) and X-ray diffraction (XRD) investigation for the microstructure behaviour and chemical element distribution inside cement-binder matrix.
Keywords— Copper Slag, Green sand, SEM, XRD, Sand Replacement.

I. INTRODUCTION

Aggregates are important constituent of concrete. Aggregates occupy about 60 to 75% of the total volume of concrete. Fine aggregate used in concrete is generally river sand. Natural sand is generally being dredged or dug from the river or lake bed causing ecological imbalance. Use of artificial aggregates is expensive and hence an alternative material for river sand is being explored. Utilization of industrial waste as aggregates not only reduces the cost but also reduces the environmental pollution.

Copper slag is an industrial waste product produced in the smelting process during the production of copper from its ore. It has a promising future in making of concrete as full or partial replacement material for fine aggregate.Copper slag is generally used as grit for blast cleaning of rough surfaces or for removal of rust, paint etc. It is a black, glassy granular material. Copper slag has a bulk density of 1.70 to 1.90 g/cc, hardness between 6 to 7 MoH Scale. In this work, copper slag obtained from Satellite Industries, Tuticorin is used.

Greensand or Green sand is either a sand or sandstone, which has a greenish color. This term is specifically applied to shallow marine sediment that contains noticeable quantities of rounded greenish grains. These grains are called glauconie sand consist of a mixture of mixed-layer clay minerals, such as smectite and glauconite mica. Greensand is also loosely applied to any glauconitic sediment.

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Green sand is composed of high quality silica sand (85-95%) – the bulk medium that resist high temperature;bentonite clay(4-10%)-used as binder; Carbonaceous additive(2-10%)-added to improve the casting surface finish; Water (2-5%)-to adjust plasticity.

Green sand has a clay content that results in percentage of material that passes at 75µm (sieve no.200, ASTM C136-06 standard test method for sieve analysis of fine and coarse aggregates) and adheres together due to clay and water. Due to carbon content, it looks black in colour, or sometimes gray. It also contains trace chemicals such as MgO,K2 O, and TiO2 .

II. MATERIALS AND EXPERIMENTAL METHODS

A. Raw Materials

cement is a crystalline compound of calcium silicates and other calcium compounds having hydraulic properties.Ordinary Portland cement 53 grade conforming to IS 8112 – 1989is to be used, and specific gravity of cement is found to be 3.15.

B. Fine aggregate

Aggregate passing the 3/8" (9.5-mm) sieve and almost entirely passing the No.4 (4.75-mm) sieve and predominantly retained on the No. 200 (75-micrometer) sieve.Locally available river sand having bulk density 1862 kg/m3 is used and the specific gravity 2.73 and fineness modulus of river sand is 3.01.

Copper slag

In India copper slag is produced by many industries one of them is Sterlite industries ltd (SIL), tuticorin tamilnadu. It is producing copper slag during the manufacture of copper metal. Currently, about 2600 tons of copper slag are produced per day and a total accumulation of around 1.5 million tons.

C. Green sand

Green sand is high quality silica sand with uniform physical characteristics. It is a by- product of ferrous and nonferrous metal casting industries, where sand has been used for centuries as a moulding material because of its thermal conductivity.

III. 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.

Rishav Garg et al., (2016), has studied the "Strength, rapid chloride penetration and microstructure study of cement mortar incorporating micro and nano silica". The microstructure and strength correlation of cement mortars on partial replacement of cement with MS, NS and MS+1%NS has been carried out on the basis of split tensile strength, compressive strength, rapid chloride penetration, carbonation and SEM-EDX analysis of cement mortar specimens. The split tensile strength and compressive strength of the cement mortar specimens with MS, NS and MS+1%NS at the curing age of 28, 56, 90 and 180 days was found to be higher as compared to conventional mortar specimens. These results were attributed to the pozzolanic action and filler effect that was found to accelerate in case of specimens with NS in comparison to that containing MS and further increased in specimens with MS+NS.

K.Mahendran and N.Arunachelam (2015), has studied Study on utilization of copper slag as fine aggregate in geopolymer concrete. The properties of six different proportions with control mix concrete and others were 10 %, 20 %, 30 %, 40% and 50% sand were replaced with copper slag are compared and discussed. The mix with Copper slag shows maximum compressive strength and split tensile strength of 71.2 N/mm2 and 4.95 N/mm2 respectively which was cured at 60 ˚C, while the mixes cured at ambient temperature attains a maximum compressive strength and split tensile strength of 38.90 N/mm2 and 3.87 N/mm2 respectively. The Scanning Electron Microscope (SEM) /Energy Dispersive X-Ray Analysis (EDAX) studies were conducted to investigate the morphology and chemical composition of the fly ash and Geopolymer concrete. Increase in the content of copper slag in place of sand, strength of concrete increases this may be influenced by presence of higher amount of silica in copper slag compared to the sand.

Khuram Rashid and Muhammad Akram Tahir (2014) has studied the " Evaluation of Concrete Compressive Strength by incorporating Used Foundry Sand" evaluate the compressive strength of concrete by utilizing three types of used foundry sand; with bentonite clay, with sodium silicate & with phenolic resin as partial replacement of fine aggregates. Compressive strength increases with increase in curing age in all cases and at 28 days of curing, 80% of compressive strength was reached in all concrete specimens and strength decreased with increase in percentage replacement of UFS.

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.

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.

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, upto 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

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concrete contains more voids, micro cracks, and capillary channels which accelerate the damage of concrete during loading.

Mosafa Khanzadi and Ali Behnood (2009) investigated the feasibility of using copper slag as coarse aggregates in high-strength concrete. 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) 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) 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 slag samples are non-toxic and pose no environmental hazard.

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. 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) 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 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.

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.

Ke Ru Wu et al (2001) studied the effect of copper slag as coarse aggregate in highperformance 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/mm2 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.

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

IV. METHODOLOGY FOR MIX PROPORTION AND TESTING OF THE SPECIMENS

Table 1.Mix design of cement mortar (1:3)

Specimen	Cement (gm)	Fine aggregates (gm)		
		River sand	Copper slag	Green sand
M1	80	240	0	0
M2	80	192	24	24
M3	80	144	48	48
M4	80	96	72	72

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A. Scanning Electron Microscopy

It is well known that, the calcium–silica–hydrate (C–S–H) is major phase present. The factors that influence the mechanical behavior of C–S–H phases are: size and shape of the particles, distribution of particles, particle concentration, particle orientation, topology of the mixture, composition of the dispersed/continuous phases and the pore structure.SEM represents a high performance method used to investigate the structure of the materials. It is defined by: easiness to prepare samples to be tested, large diversity of information reached, good resolution associated with high field depth, large and continuous range of magnifying, etc. The examination of microstructures with SEM offers two benefits as compared to optical microscopy (OM): much more resolution and magnification, as well as very large field depth giving the impression that images obtained are outstanding. Thus, the field depth in OM when magnified 1200 times is 0,08 mm, while in SEM at 10.000 times magnifying, the field depth is 10 mm. The scanning electron microscope SEM of type EVO 18 provides excellent quality imaging results from an analytical micro-scope with the capability to handle all material types

B. X RAY Diffraction

The analyses made by XRD used a DRON 3 diffractometer, with an angular range of 2q = 10– 70 degrees, at a radiation of l=1,54182 Å, voltage of 25 kV and intensity of 25 mA, in a Bragg – Brentano scheme. The diffraction samples were either powder (found by pestle milling) or cakes

C. Need For Study

The main need of this project is

1) To study the microstructure of cement mortar
2) Compressive strength, SEM and XRD studies and their results compared with control mix mortar.

V. CONCLUSION

A. The results obtained in this study indicate that the use of copper slag and green sand in mortar as substitute material for river sand give options for the employment of this massive waste as an alternative material that is environmentally sustainable and appropriate for the construction industry.
B. The replacement of copper slag and green sand in fine aggregate also shows much improved compressive strength when compared to control mix.
C. The recommended percentage replacement of sand by copper slag is 40%.
D. Copper Slag behaves similar to River Sand as it contains Silica (SiO_2) similar to sand.

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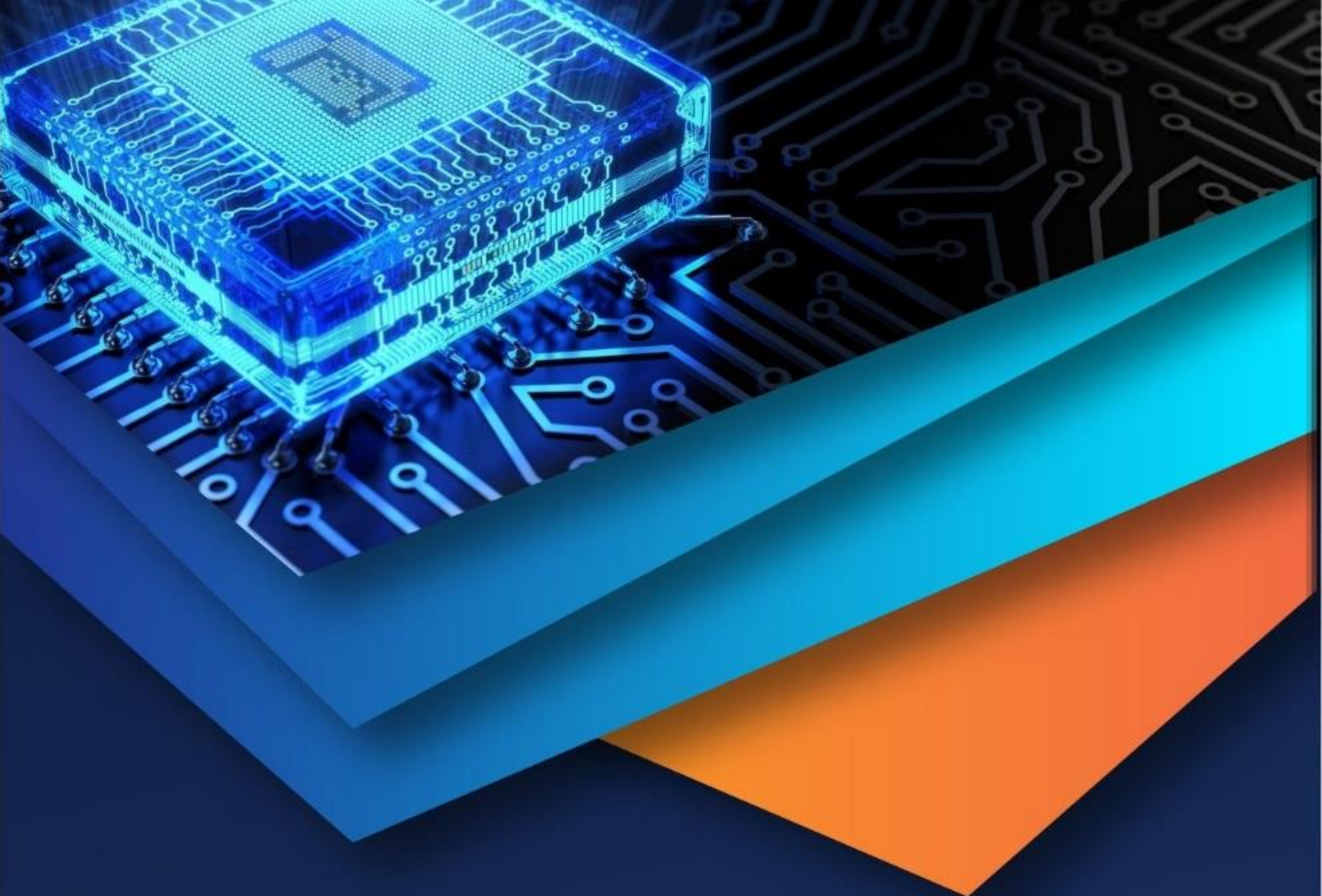

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