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REVIEW ARTICLE

EXPERIMENTAL STUDY ON PARTIAL REPLACEMENT OF FINE AGGREGATE WITH COPPER SLAG IN CONCRETE

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ABSTRACT

Use of industrial waste materials (soil) or secondary waste materials has encouraged to use in construction field for the production of cement and concrete because it contribute to reducing the consumption of natural resources. Copper slag is one of the industrial by product materials that is considered as a waste which could have a capable future in construction Industry as partial or full substitute of either cement or aggregates. Many civil engineering researchers have found it before possible to use copper slag as a concrete aggregate. Tests were conducted to determine the properties of copper slag as aggregate such as density and specific gravity. As 100% replacement of natural fine aggregate with copper slag as fine aggregate is not feasible, partial replacement at various percentage were examined. For this experimental study M30 grade concrete was used and tests were conducted for various proportions of copper slag (10%, 20%, 30% and 40%) replacement with fine aggregate (sand) in concrete. The obtained results were compared with those of control concrete made with ordinary Portland cement and sand at 7days, 14days and 28days of curing.

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INTRODUCTION

Today mostly industrial and domestic activities are associated with significant amounts of non-biodegradable solid waste, which include a wide range of plastic waste and copper slag. The research study to be undertaken intended to determine the efficiency of reusing waste plastic and copper slag in production of concrete. Usage of these industrial waste materials is a partial solution to ecological and environmental to solve problems. Use of plastic and copper slag not only helps in getting them utilized in concrete, it helps in reducing the cost of concrete making, numerous indirect benefits such as cost of landfill, saving to energy and protecting the public environment from probable pollution. Due to cost of land, space for landfill is generally impossible. So recycle and reuse of wastes materials are benefit and encouraged. From the waste materials it is possible to develop finer aggregates, it is a common construction material used almost all construction works. The reuse of waste materials in the construction industry is a great idea, due to the latest demand. Concrete is commonly used artificial construction material among the world. Requirements of aggregates for concrete and to dispose of the waste from various industries or commodities are at present important concern. At present sustainability of construction materials required for construction industry has got top priority. In this research work, main objective of this investigation is to study strength properties after partially replacing fine aggregate with copper slag. In this project we made M30 grade concrete with water- cement ratio of 0.45 and Compressive strength, split tensile strength and flexural strength were studied.

Literature Study: Al-Jabri et al., (2011) conducted study on concrete, highest compressive strength was obtained 96.8 N/mm2 using replacement of 50% copper slag with sand. From the study it was concluded that while 50 % replacement of copper slag, the compressive strength of replaced concrete increased, beyond that it reduced significantly. Arivalagan (2013) studied possibility of using copper as a replacement of sand in concrete mixtures. The test conducted to adding copper slag to sand in percentages ranging from 0%, 20%. 40% 6 80% and 100%. The tested of compression strength test, splitting tensile test and flexural strength.

The highest compressive strength gained at 35.11MPa at 40% replacement and the equivalent strength for control mix was 30MPa. These results of research paper showed that the possibility of using copper slag as fine aggregate in concrete. Binaya et. al (2014) studied, sand partially replaced with copper slag in concrete production , while manufacturing process of M20 Grade mix, the maximum strength was attained with 40 % of Copper slag replacement of sand. Binaya Patnaik et al.(2015) studied , concrete filled with copper slag as partial replacement of sand with an mix ratio of M20 and M30. In addition to add copper, it found that decreasing of compressive strength while inclusion of crumbled fibre increasing was found. Brindha and Nagan (2011) conducted research study on the durability properties of copper slag admixed with concrete from their study it was found that the concrete with copper slag has less resistance to the H_2So_4 solution than the normal concrete. B. Harini et al. (2015) conducted research work on strength properties of M30 grade concrete filled with different waste plastic of proportions are5 %, 6%, 8%, 10%, 15%, 20% by volume. While filled plastic wastes decrease in compressive strength when the ratio of plastic to aggregate was increased. From this research it was found that cement was partially replaced by 10%, 15% of silica fume was higher than reference mix. Khanzadi et al., (2009) found the mechanical properties while incorporate copper slag can be used fruitfully as aggregate (coarse) for High Strength Concrete as tensile and flexural strength of concrete will also increase moderately also improve to supporting the environment. Najimi et al.(2011) investigate from their research use of copper slag in concrete , improve sulfate attack , this makes durable of concrete when adding copper slag when compare to normal concrete. This is clearly indicate use of copper slag, natural resources saved and improve the sustainability. Simiha Akcozoglu (2009) conducted research on by using PET plastic wastes , from the research it was concluded that use of tattered PET granules less unit weight, so it reduces the unit weight of concrete. which gives decrease in dead weight of building. It will help to reduce the seismic risk of building. Mariaenrica Foregone (2010) had conducted an investigation on using recycled PET bot as fine aggregate in concrete and concluded the workability, compressive strength, split tensile strength is slightly lower than reference concrete moderately higher ductility. Semiha Akcaozog (2011) had conducted an investigation on mortars by using PET as aggregate and studied the effects of Granulated Blast Furnace Slag and Fly ash materials, from this study it concluded that while using flyash decreased compressive, tensile strength, compared to normal specimens. While using GGBS and flyash increases carbonation. So carbon reduced measures had taken for using mineral admixtures. Wu et al. (2010) found that copper slag has less moisture absorption and soft glassy texture with notable compressibility this can increase the dynamic behavior and workability of concrete mixture.

Objectives of the research: There were two main objectives of the research. First is to find the optimum proportion/percentage of copper slag that can be used as a replacement or substitute material for fine aggregate. Secondly, to find the compressive strength, split tensile strength and flexural of copper slag as partial replacement of fine aggregate in concrete specimens.

Materials used for test

Cement: Cement is a artificial material with a combination properties of adhesive and cohesive, This mineral particles make it capable of bonding. The cement is produced by mixing and grounding of limestone, iron ore, alumina and silica. This mixture is heated in a rotary kiln in a temperature of about 1600° C. This process makes material to break down and recombine into new compound is called clinker. After clinker process, cooling the clinker is ground to a fine powder from which obtained cement material.

Aggregates: Aggregate is fine and coarse granular material such as sand, gravel, crushed stone, and blast furnace slag that usually occupies approximately 60-70% of the volume of concrete. This has reduced volume changes due to drying shrinkage of the water-cement paste. Generally Aggregate properties affects workability of hardened plastic concrete like durability, strength, thermal properties and density. Aggregates can be classified as fine aggregate and coarse aggregates based on the size and also as natural or artificial, with respect to source and method of preparation.

Coarse aggregates: Well graded natural coarse aggregates obtained from quarry near Chennai. Aggregates passing 20 mm sieve but retained in 10 mm sieve were used. The obtained natural coarse aggregates were again sieved to remove quarry dust and other small particles if present in nature.The sieve sizes in commonly used for particle size distribution of coarse aggregates were 50, 37.5, 25, 19, 10, and 4.75 for coarse aggregate. The aggregates were collected and used roughly 2kg by mass. The grading of different proportions of sizes of particles making up the aggregates for test this called as grading of aggregates. The grading has measured in term of the percentage by mass passing the various sieves. While continuously graded aggregates for concrete in particle size ranging from the largest to the smallest.

Fine aggregates: The sieve sizes in general used for particle size distribution of fine aggregates were 10 , 4.75, 2.36, 1.18 mm and 600, 300,150 and 75µm. This test consisted of dividing up and separating by means of a series of test sieves named here above, a material into several particle size classifications of decreasing sizes. The value of the particles retained on the different sieves was related to the initial mass of the material. The cumulative percentages passing of aggregates of each sieve were presented in numerical form. The properties of fine aggregate is tabulated in Table 1 below.

Table 1. Properties of Fine Aggregate

Sl.No.	Property	Value
1	Specific Gravity	2. 64
2	Fineness Modulus	2.50
3	Bulk Density	1562

Copper slag from Sterlite Industries India Limited (SIIL), Tuticorin, Tamil Nadu, India was made use of this research work. The Physical properties of copper slag is black glassy and granular at available from sources also having similar particle size proportion like sand. The specific gravity of slag falls between 3.35 and 3.95. The bulk density of copper slag is in the range of 1.85 to 2.17 kg/ m3 which is nearly same to the bulk density of normal fine aggregate. The hardness property of the copper slag between 6 and 7 in MoH scale. This value equal to the hardness of gypsum. The pH varies from 6.6 to 7.2. The moisture content present in slag was found to be less than 0.5%. Copper slag delayed both initial and final setting times with cement paste. Copper slag has a good abrasion resistance and good stability. The chemical composition of copper slag is tabulated in Table 2 below.

Table 2. Chemical composition of copper slag

Sl.No	Chemical composition	%of composition
1	Fe2O3	68.30
2	SiO2	25.84
3	Al2O3	0.22
4	CaO	0.20
5	Na2 O	0.63
6	K2O	0.23
7	TiO2	0.41
8	SO3	0.12
9	CuO	1.10
10	Sulphide sulphur	0.35

Casting and Testing of samples: Weight batching method was used and four batches were obtained. Mass substitution of sand with plastic particles was made at percentages of 0%, 10%, 20% and 30% for the four batches respectively. The water content was kept constant for all the batches of concrete mixes. Mix ratio adopted was class M30 of (1:1.8:3.3). Casting is the process of making of concrete blocks. Casting of concrete blocks can be done by placing the concrete mix in the moulds.

Figure 1. Copper slag

Figure 2. Casting of cubes

Figure 3. Curing of cubes

The moulds which is used for the castings the cube, The size of the cube molds are 150* 150* 150 mm. The first step of the casting is the preparation of the concrete. The concrete is prepared by mixing cement sand and aggregate. The mix is prepared in M30 grade. The ratio of the mixture is 1: 1.8: 3.3. The concrete mix is prepared with 0.45 water-cement ratio. Before placing the concrete into the mould, the mould is prepared properly.

The inside of the moulds should have fine texture and the inside portion should be polished with the oil. The specimens were removed from the moulds and marked with details of type of mix, date of casting, duration for curing and the determined crushing date, using a water proof marker then placed in water of temperature about 200C such that they were completely submerged. Some samples were cured for 7days and others 14 and 28days so as to determine how the duration of curing would affect strength of concrete. Curing took place by hardening of the concrete. The temperature is play main role of progress of the reactions of hydration and subsequently affected the growth of strength of concrete.

RESULTS AND DISCUSSION

Compressive Strength Test: After curing the cubes for 7 days, 14 days and 28 days periods, they were uncovered in readiness for compression tests. The cubes were then placed with the cast faces in contact with the platens of the testing machine that is the position of the cube when testing should be at right angle to that of casting. The test load was then gradually applied on the specimens until failure happened. i.e the cube crashed.

Compressive Strength (N/mm^2) = Ultimate load in 'N' /Area of cross section in 'mm^2 '
Compressive strength of the specimen is determined by using following formula
Compressive strength = load at failure/ area of specimen

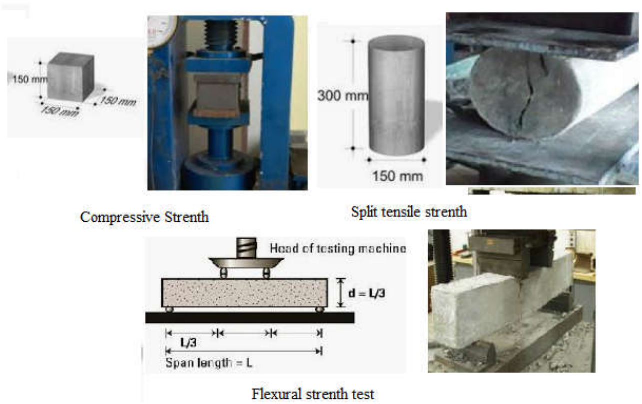

Figure 4. Test set up on Compression test, Split Tensile Test, and Flexural test

Table 3. Compressive Strength Performance at 7, 14 and 28days

Sl.No	Specimen	Compressive Strength (MPa)		
		7 days	14 days	28 days
1	NMC	19.11	26.44	27.77
2	CS10	19.70	27.38	28.84
3	CS20	20.18	28.11	29.31
4	CS30	21.22	29.81	30.76
5	CS40	20.78	27.51	28.15

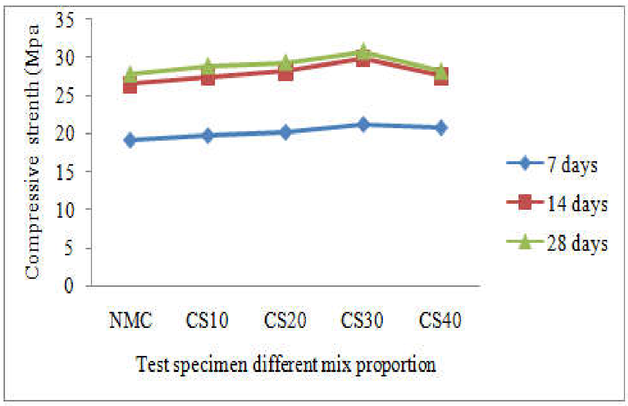

Figure 6. Split tensile strength values of copper slag concrete for 7,14 and 28days

Split Tensile Strength Test: The test was conducted using a similar UTM to work out the tensile strength of concrete specimens. The split tensile test was conducted cylindrical specimens of 150mm diameter, and 300mm length. The specimens were tested after taking them from water at 7th, 14th and 28th day. From it was observed that after beyond 30% replacement of copper slag strength was reduced. Table 4 shows the split tensile strength of the copper slag and normal concrete specimens and Figure 8 shows its visual observation.

Split tensile strength decreases steadily with increasing percentage of copper slag replacement and the optimum strength is at 30 % to 40% replacement level.

Flexural Strength Test: This test was conducted to check the capability of concrete to resist against bending failure. This test was conducted by loading the specimens of unreinforced concrete beam of 100x100x750 mm size. The material placed under loading type of two point loading testing setup. The strength of a material in bending is measured as the stress on the outermost fibres of a testing specimen, at the direct to failure. The average flexural strength value of specimens for each category at the age of 7 days, 14 days and 28 days is tabulated as shown in Table 5. There is consistency in the flexural strength of concrete with the inclusion and slightly increase in the percentage of copper slag as fine aggregate when compared to other percentage of replacement of fine aggregate. Figure.7 shows the flexural strength of the specimens. Optimum flexural strength was obtained at 30% replacement.

Table 5. Flexural strength values of copper slag aggregate concrete for 7,14 and 28days

Sl.No	Specimen	Flexural Strength (MPa)		
		7 days	14 days	28 days
1	NMC	2.5	3.35	4.1
2	CS10	2.60	3.60	4.40
3	CS20	2.66	3.75	4.63
4	CS30	2.70	3.90	4.68
5	CS40	2.54	3.65	4.52

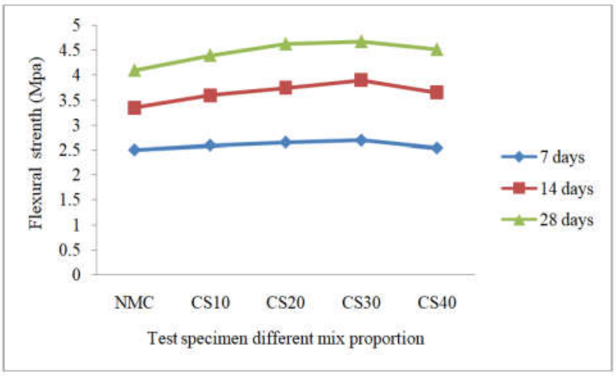

Figure 7. Flexural strength values of copper slag concrete for 7,14 and 28days

CONCLUSION

In this research, copper slag was used as a partial replacement of sand in concrete. The mix was studied and compared with the control mix having normal aggregates. The following conclusions were obtained from these results. The modified concrete mix, with addition of copper slag as fine aggregate replacing conventional aggregate up to 30 % gives strength with in permissible limit.

As of experimental study we found that by increase of replacement of fine aggregate it is found that strength is decreasing. While partial replacement of fine aggregate with copper slag in concrete is increases the density of concrete, it led to increases the self-weight of the concrete. The use of copper slag in concrete can reduce the land fill and environmental issues. This method of aggregate replacement concrete is useful where and when aggregates are in crisis also the natural resources can be conserved.

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