SUSTAINABILITY OF CONCRETE USING COPPER SLAG AS REPLACEMENT FOR RIVER SAND

Ankem Bhargav[1], M. Ramachandra Rao[2]

[1]Student, Department of Civil engineering, (NRI Institute of Technology - An Autonomous Engineering College – Vijayawada), Pothavarappadu, Nunna Rd, Agiripalli,, AP- 521212
[2]Associate professor, Department of Civil engineering, (NRI Institute of Technology - An Autonomous Engineering College – Vijayawada), Pothavarappadu, Nunna Rd, Agiripalli, AP- 521212

Abstract:
This work 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 project reports the effect of concrete using copper slag and M-sand as fine aggregate replacement. In this project work, the concrete grade M60 was selected and IS method was used for mix design. The properties of materials for cement, fine aggregate, coarse aggregate, copper slag and M-sand were studied for mix design. The various strength of concrete like compressive, split tensile, flexural were studied for various replacement of fine aggregate using copper slag and M-sand that are 0%,10%,20%,30%,40%,50% and 60%. The maximum compressive strength of concrete attained at 40% replacement of fine aggregate at 7, 14 and 28 days. The split tensile strength and the flexural strength were also obtained higher strength at 40% of replacement level at 28 days
Keywords: Keywords Cement, fine aggregate, coarse aggregate, copper slag, M-sand

1.0 INTRODUCTION

In India, by-products and waste materials are being generated by various types of industries. Disposal of waste materials effects the environment in various zones. Therefore, these waste materials can be recycled and it is great potential in construction industry. Many researchers found that concrete made with wastes and by-products like fly ash, silica fume, copper slag etc acquires excellent properties than the conventional concrete in terms of strength, performance and durability. Hence, in this project, copper slag is taken to investigate its suitability as a replacement material for fine aggregate while making concrete. Copper slag is an industrial by-product material produced during the smelting and refining process of copper, which can be used for a surprising number of applications in the construction field. It is also having similar physical properties of sand, considered as an alternative material to the river sand. It is the waste product material of copper. Disposal of this waste causes environmental pollution. The construction field is the only area where the safe use of waste material like copper slag is possible. When it is taken as a replacement material in concrete, it lessens the environmental pollution, space problem and also lessens the cost of concrete.

This sand is obtained by forming pits in soils.

- It is excavated from a depth of about 1-2 m from the ground level.
- This sand is found as deposits in soil and it consists of sharp angular grains, which are free from salts.
- It serves as an excellent material for mortar or concrete work.
- Pit sand must be made free from clay and other organic materials before it can be used in mortar.
- A coating of oxide of iron over the sand grains should be removed.

RIVER SAND:

This sand is widely used for all purposes. It is obtained from the banks or beds of rivers and it consists of fine rounded grains. The presence of fine rounded grains is due to mutual attrition under the action of water current.

- The river sand is available in clean conditions.
- The river sand is almost white in color

CLASSIFICATION OF SAND:

Based on the grain size distribution

Fine sand: The sand passing through a sieve with clear openings of 1.5875 mm is known as fine sand. Fine sand is mainly used for plastering.

Coarse sand: The sand passing through a sieve with clear openings of 3.175 mm is known as coarse sand. It is generally used for masonry work.

Gravelly sand: The sand passing through a sieve with clear openings of 7.62 mm is known as gravelly sand. It is generally used for concrete work.

Benefits of Alternative Sands in Construction

Natural or River sand are weathered and worn-out particles of rocks and are of various grades or sizes depending upon the amount of wearing. Now-a-days good sand is not readily available; it is transported from a long distance. Those resources are also exhausting very rapidly. So it is a need of the time to find some substitute to natural river sand

- Wide availability of sources gives flexibility of manufacturing in nearby construction sites, thus driving down transportation costs and assuring timely supply to meet demand.
- Size of particles can be controlled in CRS and RFA.
- All alternative sands are eco-friendly, with low carbon-dioxide emission.
- There is no exploitation of river beds, thus preventing environmental catastrophes like water scarcity, ground water depletion etc.

Advantages Of Copper Slag:

- Reduces the construction cost due to saving in material cost.
- Reduces the heat of hydration.
- Refinement of pore pressure.
- Reduces permeability.
- Reduces the demand for primary natural resources.
- Reduces the environmental impact due to quarrying and aggregate mining.

Objectives of research work:

In this work, an extensive study using copper slag has been carried out to investigate the following,

- To find the optimum proportion of Copper Slag that can be used as a replacement substitute material for fine aggregate in concrete
- To evaluate mechanical properties by use of copper slag in concrete specimens.
- To determined Strength, Workability, and Durability by using copper slag as fully replacement of River using different proportion.

2.0 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. 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. 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

G. Esakki Muthu et. al. [1] investigated the micro formation of cement mixture with green sand and copper slag like a substitute of fine aggregate. The replacement of green sand and copper slag will be regularly from 10%, 20%, and 30% by the weight of fine collection. The results obtained in this research point to that the main function of copper scum and green sand in mortar as alternate material for river Sand gives options for the consumption of this huge waste materials as an alternative material that is environmentally sustainable and appropriate for the building manufacturing. **Mr. Neel P. Patel et. al. [2]** they investigated the feasible employ of copper scum for the fractional exchange of sand. Since copper scum is a more density material and contains around 45% of Fe2O3. Depend on restricted investigational analysis concerning Slump Value, Compressive potency, Flexural potency and UPV Test of Concrete for M-35 and M40 Grade made from Metal industries waste. **Mankare Ulka S et. Al. [3]** optimize solution regarding the capacity of Bagasse residue as a cement exchanging material that is comparable to that of Portland Pozzolana Cement and Copper slag as a fine collection exchanging material. The functions of these contaminants have then been evaluated together at the clean and solidification state **Dr. A. Leema rose, P. Suganya et al [4]** 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. **Chinmay buddhadev, [5]** Protecting the depleting natural sand resource and the shore line is a major concern of the day. It is essential today, to reduce excessive consumption of the natural river sand and there by prevent sand mining. It is possible by utilization of industrial by-products as well as other waste materials in the production of normal concrete and HSC. These products can be used as partial and/or full replacement of cement or/and aggregates or as admixtures. **Mr. Neel P. Patel, [4]** Cement, sand and aggregate are essential needs for any construction industry. Sand is a major material used for preparation of mortar and concrete and plays a most important role in mix design. In general consumption of natural sand is high, due to the large use of concrete and mortar. Hence the demand of natural sand is very high in developing countries to satisfy the rapid infrastructure growth. The developing country like India facing shortage of good quality natural sand and particularly in India, natural sand deposits are being used up and causing serious threat to environment as well as the society. **Chinmay buddhadev et. al. [5]** they have experimented and investigate the result of copper scums by exchange it by the fine aggregates and investigates the properties of concrete. For the research they arranged five mix designs with special proportions of copper scum varies from 0% to 35% and 100%. Concrete mixture substance was evaluated for density, compressive force, tensile force, flexural potency and stability. **M. R. Amarnaath et. al. [6]** they have experimented and investigate the result of copper scums by exchange it by the fine aggregates and investigates the properties of concrete. For the research they arranged five mix designs with special proportions of copper scum varies from 0% to 35% and 100%. Concrete mixture substance was evaluated for density, compressive force, tensile force, flexural potency and stability. **Binaya Patnaik, Seshadri Sekhar et. al. [7]** this study based on experimental investigation they conclude that the strength of concrete increases with cost effective and without depleting the natural resources. By doing this project they reduced the consumption of fine aggregate by 50% than conventional concrete, at this proportion concrete will give maximum strength. By replacing the fine aggregate with 50% copper slag the cost saving was found to be 20%. **Pranshu Saxena et. al. [8]** they studied about the strength parameter of concrete having copper slag as a substitute of sand and outcome have been presented by them. Two different kinds 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

METHODOLOGY

Copper slag, which is the waste material produced in the extraction process of copper metal in refinery plants, has low cost and its application as a fine aggregate in concrete production have many environmental benefits such as waste recycling and solves disposal problems. It has been observed that up to 100 % replacement, copper slag can be effectively used as replacement for fine aggregate. The compressive strength increases with increase in percentage of combine mixes (copper slag and ferrous slag). copper slag is a glassy granular material with high specific gravity. Particle sizes are of the order of sand and have a potential for use as fine aggregate in concrete. In order to reduce the accumulation of copper slag and also to an alternate material for sand, copper slag was used as a replacement material for sand in cement concrete. It shows that the water consumed by the copper slag during mixing is very less as compared with river sand.

Materials:

a) Cement b) coarse aggregate c) Fine aggregate (river sand), d) M-sand, e) copper slag, f) Sulphonated Naphthalene Formaldehyde SP430, g) Water. a) Cement: Ordinary Portland Cement of 53-grade was used as it satisfied the requirements of IS: 269- 1969 and results have been tabulated in table

Properties of cement	
Specific gravity	3.15
Consistency	33%
Fineness	6.3
Initial Setting Time	45 minute
Final Setting Time	480 minutes

Coarse Aggregate: coarse aggregate shall comply with the requirement of IS 383 as for as possible crushed Aggregate shall be used for ensuring adequate durability. The aggregate used for concrete the nominal maxi size of coarse aggregate used in Production of shall be 20 mm.

Fine aggregate: Fine aggregate shall conform to requirement of IS 383 for river sand

Test	Types of Aggregate		
	Coarse	Fine	copper
Specific Gravity	2.9	2.88	3.51
Water Absorption	0.5%	3.5%	Nil
Moisture content	Nil	Nil	Nil

Cement:
Cement, commonly Portland cement, and other cementitious materials such as fly ash and slag cement, serve as a binder for the aggregate. The cement used in this study is of OPC 53 grade conforming to IS 12269
Water: Water is then mixed with this dry composite, which produces a semi-liquid that workers can shape (typically by pouring it into a form). The concrete solidifies and hardens to rock-hard strength through a chemical process called hydration. The water reacts with the cement, which bonds the other components together, creating a robust stone-like material. The good quality water is used in this study.
Copper slag:
Copper slag is an irregular, black, glassy and granular in nature and its properties are similar to the river sand. In this project, Copper slag used is brought from Sterile Industries India Ltd, Tuticorin. Every ton of copper will generate approximately 2.2-3 tons of copper slag Sterlite Industries India Ltd produces 400,000t/year of copper and during the process, around 800,000t of copper slag is generated in a year. The chemical traces such as copper, sulphate and alumina present in the slag are not harmful.

Figure 1: Copper slag

Table 1-: Physical Properties of Copper Slag

PROPERTY	VALUE
Specific Gravity	3.54
Water Absorption	0.32%
Fineness Modulus	5.55

The test results of concrete were obtained by adding copper slag to sand in various percentages ranging from 0%, 20%. 40%, 60%, 80% and 100% All specimens were cured for 28 days before compression strength test, splitting tensile test and flexural strength. The highest compressive strength obtained was 35.11MPa (for 40% replacement) and the corresponding strength for control mix was 30MPa.

Plastizers: Sulphonated Naphthalene Formaldehyde SP430 is used as directed by the manufacture to improve the workability of fresh concrete mix. g) Water: The water used for mixing concrete mix should be potable drinking water having PH 6 TO 8.

As per design M60 Grade Material Requirement for 1 M3	
Material	Quantity in kg
Cement	466
Sand	856
Aggregate	1171
Water	156 liter

Foundry sand:

It consists primarily of silica sand, coated with a thin film of burnt carbon residual binder and dust. The fine aggregate has been replaced by used foundry sand accordingly in the range of 0%, 10%, 30% & 50% by weight for M-20 grade concrete. Concrete mixtures were produced, tested and compared in terms of compressive and flexural strength with the conventional concrete. These tests were carried out to evaluate the mechanical properties for 7, 14 and 28 days. This research work is to investigate the behaviour of concrete while replacing used foundry sand in different proportion in concrete. This low-cost concrete with good strength is used in rigid pavement for 3000 commercial vehicles per day and Dry Lean Concrete (DLC) 100mm thick for national highway to make it eco-friendly.

River sand:

River sand is a widely used construction material in Hong Kong, especially in the production of concrete and cement-sand mortar

- The Construction Industry Council has launched a research project entitled "Research on River Sand Substitutes for Concrete Production and Cement Sand Mortar Production".
- To identify alternative materials to supplement river sand, the research will go through two phases – The first phase (Phase One) of the research aims to identify suitable river sand substitutes for practical applications in the local construction industry

Design Mix procedure:

In India, there is big requirement of aggregates mostly from civil engineering industry, for road and concrete production. But nowadays it is a very complex difficulty for accessibility of fine aggregates. So the researchers developed waste management plans to relate for substitute of fine aggregates for specific needs. In Present Scenario one of the most important replacing materials for fine aggregates is copper slag. It produces when copper metal produced by extraction process then copper slag is generated in large amount in the production of copper metal. About 2-2.5 tonnes of copper slag produced for each 1 ton of copper production. Utilization of copper slag in concrete has many environmental benefits for example waste recycling and resolve disposal problems. Copper slag consists mechanical and chemical properties that is eligible as the material to be used in production of concrete as a partial replacement as a substitute for aggregates. Mechanical property of copper slag has good sound characteristics, good abrasion resistance and good stability for aggregate use. Here an effort has been completed to accumulate the various studies done on the replacement of copper slag in fine aggregate to judge the strength of concrete

The HSC is defined as higher concrete whose characteristic strength ranges from 50 and above. Hence for my work I'm considering M60 grade concrete. The mix design for M60 grade concrete is carried out using the

Indian standard code 10262:2009. For which the water cement ratio is kept as the least value of 0.35 for the slump value is assumed as 100mm, the fine.

Preparation and Casting of Test Specimens

- 150 mm x 150 mm x 150 mm cubes were cast for compression test with replacement of 0%, 20%, 40%, and 60%, replacement of copper slag. The specimens were demoulded after 24 hours and tested for 7 days, 14 days and 28 days of curing.
- 150 mm x 300 mm cylinders were cast for split tensile test with replacement of 0%, 20%, 40%, 60%, replacement of copper slag. The specimens were demoulded after 24 hours and tested for 7 days, 14 days and 28 days of curing.

Aggregate of Zone II, coarse aggregate of 20mm size and below

- Cement = 446 Kg/m3
- Water = 156 liter
- Fine Aggregate = 856 Kg/m3
- Coarse Aggregate = 1171 Kg/m3
- Admixture = 2% of Sulphonated Naphthalene Formaldehyde SP430
- The proportion for the mix is 1:1.92:2.62:0.35

4.0 RESULTS AND DISCUSSIONS

The utilization of industrial waste or secondary materials has encouraged the production of cement and concrete in construction field. New by-products and waste materials are being generated by various industries. Dumping or disposal of waste materials causes environmental and health problems Therefore, recycling of waste materials is a great potential in concrete industry. For many years, by-products such as fly ash, silica fume and slag were considered as waste materials. Concrete prepared with such materials showed improvement in workability and durability compared to normal concrete and has been used in the construction of power, chemical plants and under-water structures. Copper slag is an industrial by-product material produced from the process of manufacturing copper. For every ton of copper production, about 2.2 tonnes of copper slag is generated. It has been estimated that approximately 24.6 million tons of slag are generated from the world copper industry. Although copper slag is widely used in the sand blasting industry and in the manufacturing of abrasive tools, the remainder is disposed of without any further reuse or reclamation. The use of copper slag in the concrete industry as a replacement for cement can have the benefit of reducing the costs of disposal and help in protecting the environment. Despite the fact that several studies have been reported on the effect of copper slag replacement on the properties of Concrete, further investigations are necessary in order to obtain a comprehensive understanding that would provide an engineering base to allow the use of copper slag in concrete.

Experimental investigation:

The fresh property test that is considered is the slump cone test. The result obtained for the slump cone test is

Table 2: Slump Values of different mixes

Slump Values of different mixes	
Concrete Mix	Slump Value (MM)
0%	38
10%	30
20%	25
30%	21
40%	18

The cubes casted are of 150 x 150 x 150mm in dimension. The cylinders are of 150mm in diameter and 300mm in length. The prisms are of 100m x 100mm x 500mm. The cubes, cylinders and prisms are kept for curing for the duration of 7, 14 and 28 days in water.

CUBE BEFORE TESTING:

The workability of the fresh concrete was determined by the slump test as given in IS: 1199 (1959). The density of concrete was determined by using cube specimens of size 150 mm×150 mm× 150 mm in the wet condition. The density, compressive strength and split tensile strength were determined in accordance with the provisions

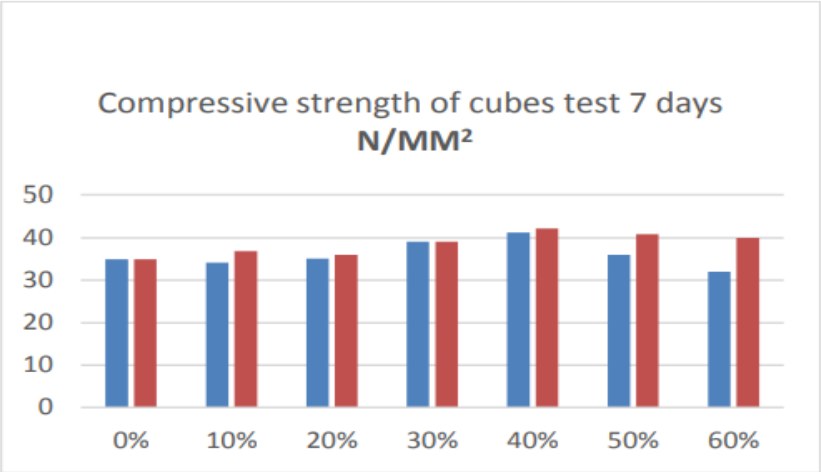
of IS: 516 The compression test was done on cubes of size 150 mm×150 mm× 150 mm in a compression testing machine of capacity 2000 kN. The cube compressive strength was determined at 7 and 28 days of curing period. The load was applied gradually at a rate of 14 N/mm2 per minute. The failure load was noted and the compressive strength was calculated.

Experimental results:

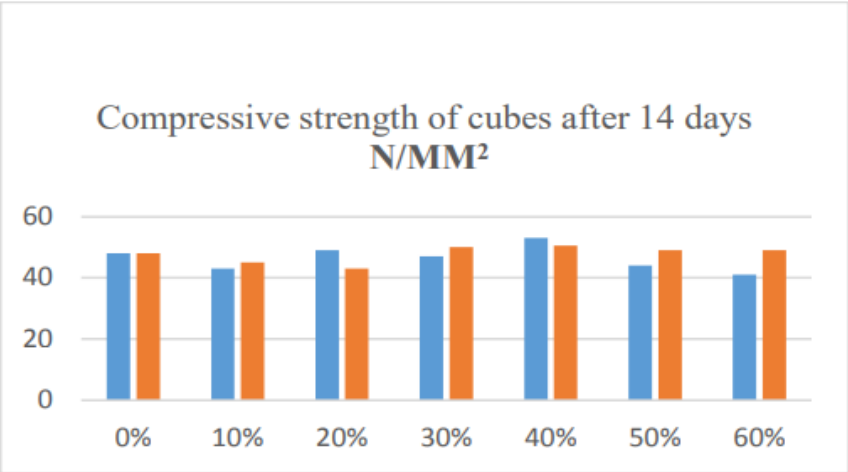
The strength test that are considered for are Compressive strength, split tensile and the flexural strength test.

Table 3: Compressive strength of cubes 7 days N/mm2

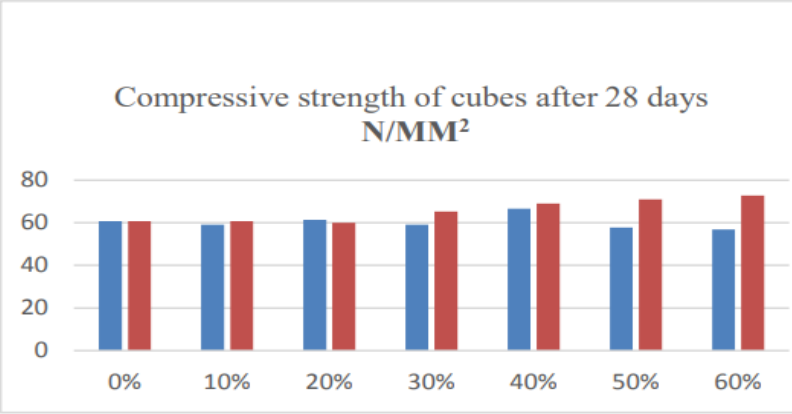
Compressive strength of cubes 7 days N/mm^2		
% replacement	Copper slag	River sand
0%	35.9	35.9
10%	36.2	36.88
20%	37.1	38.23
30%	39.11	39.11
40%	41.3	42.22
50%	36	40.88
60%	32.50	40



Graph 1: Compressive strength of cubes 7 days N/mm2

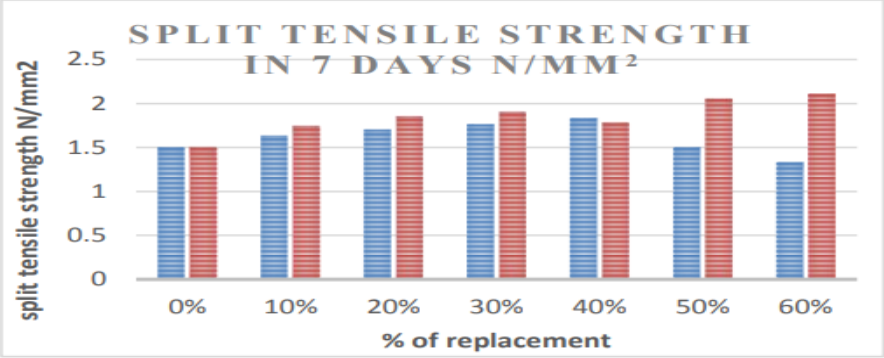


Graph 2: Compressive strength of cubes after 14 days N/MM2

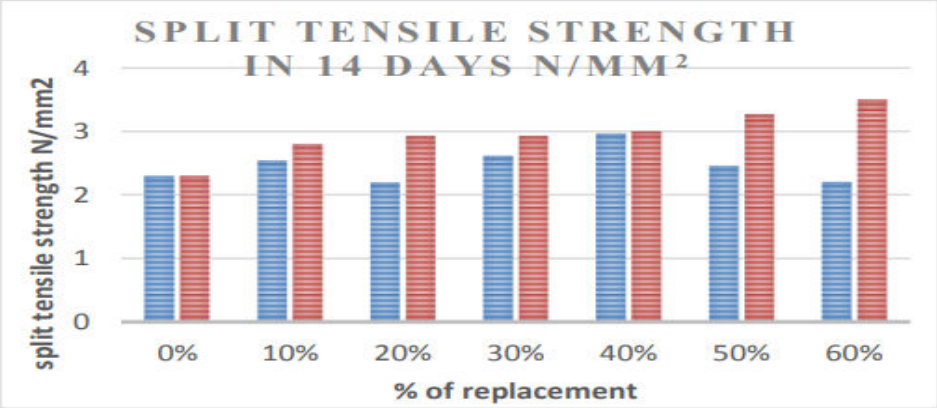


Graph 3: Compressive strength of cubes 28 days N/mm2

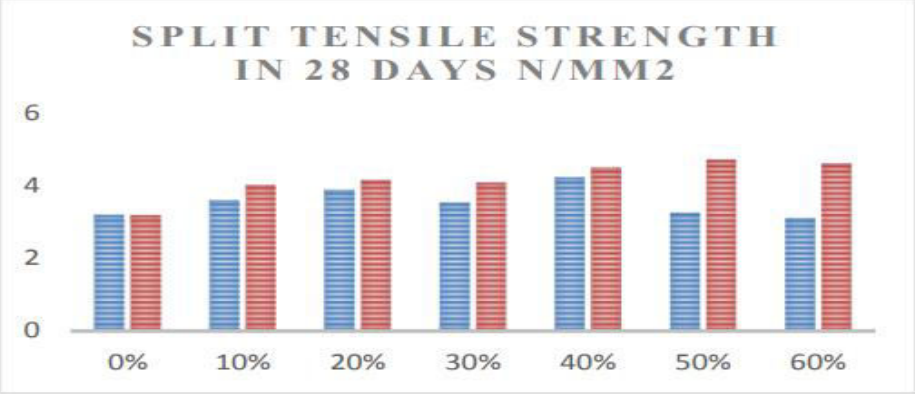
SPLIT TENSILE STRENGTH:



Graph 4: Split tensile strength of 7 days (N/mm^2)

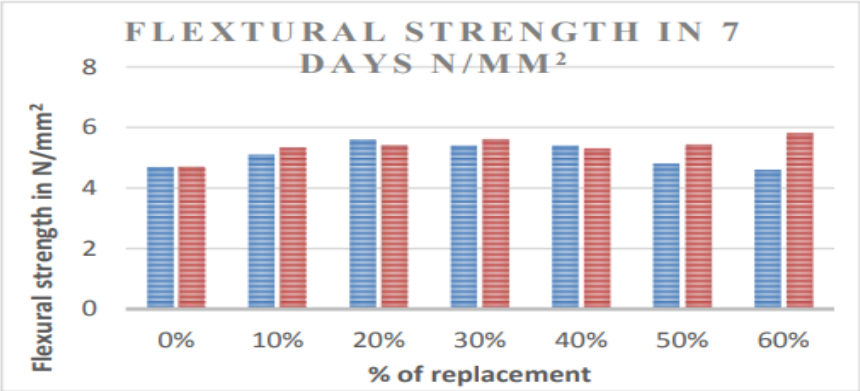


Graph 5: Split tensile strength of 14 days (N/mm2)

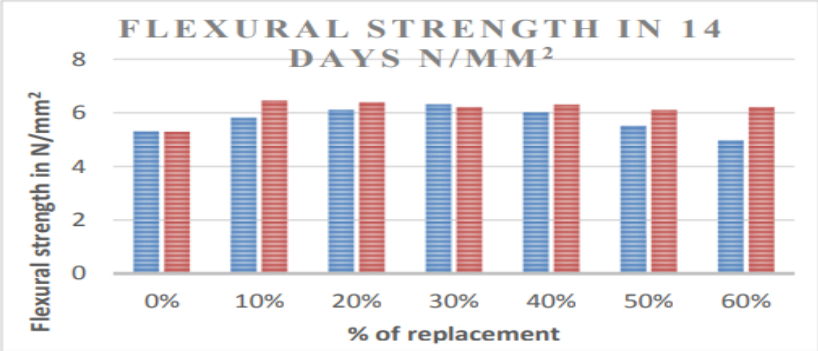


Graph 6: Split tensile strength of 28 days (N/mm2)

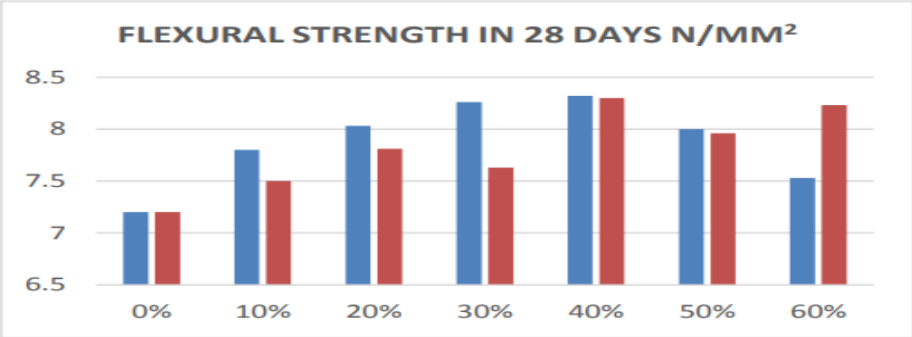
FLEXURAL STRENGTH:



Graph 7: Flexural strength in 7 days (N/mm^2)



Graph 8: Flexural strength in 14 days (N/mm2)



Graph 9: Flexural strength in 28 days (N/mm2)

CONCLUSIONS

Copper Slag behaves similar to River Sand, for its use as fine aggregate (partially or in blending) in Concrete mixes. Addition of Copper Slag in Concrete increases the density, thereby the self-weight of Concrete. The results showed that the workability of Concrete increased substantially with increase of Copper Slag content in the concrete mixture due to the low water absorption, coarser (in nature than sand) and glassy surface of copper slag, thereby the Strength properties also improved. The Compressive Strength of Concrete is comparable to the control mix up to 40% of Copper Slag substitution, but they decrease with a further increase in Copper Slag contents (due to the increase of free water content in the mix). Compressive Strength of Copper Slag admixture Concrete, increased due to high toughness of Copper Slag

- Copper slag has granular texture and also a higher specific gravity and hence is a denser material when compared to river sand.
- Water absorption in copper slag is observed to be almost 50% less than that of river sand which helps in saving water

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