STUDIES ON PARTIAL REPLACEMENT OF FINE AGGREGATES BY COPPER SLAG IN CONCRETE

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Abstract: *Industrial activities are producing huge quantum of expedient products and also by-products of minimal importance. These by-products generally end up in land filling or dumping, causing a problem to the local municipal authorities. Increased construction and industrial activities has increased production of copper in recent days, which in turn is producing copper slag as a by-product. Copper slag has no or less industrial application and hence it ends up in land filling. Concrete being a versatile material, offers a platform to confine and gallop these industrial waste materials in it as a component. Copper slag can be used in concrete as fine aggregate to solves the problem of waste disposal. In this study copper slag is partially replaced for fine aggregates at various replacement levels in concrete. From the studies it is proved that, copper slag can partially replace the fine aggregate, there by contributing to reduce the impact of sand mining. As this concrete reduces the raw material usage and ill-effects on environment, it can be considered as an eco-friendly concrete*

Keywords: Concrete, Fine aggregate, Manufactured sand, Copper slag, Eco-friendly concrete

1. INTRODUCTION:

Concrete is the broadly accepted building element which forms a homogeneous mass after hydration. It is composed of aggregates and paste matrix. Major constitute of concrete is aggregates with a stake of about 75% of volume [1]. Increased rate of developmental activities has escalated the volume of concrete utilization. Increased concrete production indirectly increases the exploitation of natural sand. Extreme river sand dredging will have adverse effect on aquatic organisms and also deepen the river beds, in turn causing ground water depletion. Extensively exploited alternative of river sand is Manufactured sand (M-sand). However, over exploitation of quarry pits might cause ill effects on surrounding eco system and can also lead to risk of landslides [2][3][4]. Escalated cost and shortfall of concrete ingredients led to adoption of alternative of fine aggregates. If the material is inert and not affecting the fresh and hardened properties it can be adopted as fine aggregate in concrete [5].

Advent of industrial revolution has led to exploitation of resources to manufacture specific end products. These activities are creating large quantity of industrial wastes, which is having no or little industrial value. It is difficult to handle and dispose such industrial wastes. One such waste is copper slag, which is produced during pyrometallurgical extraction of copper. For 1ton copper production, approximately 2.2 tonnes of slag is manufactured[4][6]. Advanced material requirements is generating lot of industrial wastes and hence recycling of such materials has great potential in concrete sector[6]. Replacement of natural fine aggregates by copper slag improves physical strength and durability at same workability[7].

Replacement of fine aggregates by 40% of copper slag in concrete exhibit enhanced strength, reduced chemical ingress and lest water absorption when compared to other replacement levels[4]. Copper slag escalate the strength of mortar and concrete and it has the potential replace about 40-50% of natural fine aggregates[6]. Chloride ingress and chloride induced corrosion of steel bars can be reduced by the incorporation of copper slag[7]. By replacing more than 20% of fine aggregates with copper slag, improved workability to nullify the usage of superplasticizer and also the hardened concrete exhibited low water absorption[8].

2. MATERIALS USED

Materials used for this experimental studies were examined as per the IS Codes.

Coarse Aggregates (CA)

Coarse aggregates ranging from 20mm to 4.75mm was procured from a local quarry. As per IS 2386-1988 part-3 [9] properties of coarse aggregates was determined and represented in Table 1.

Table 1: Properties of coarse aggregate

Features of aggregates	Obtained values
Fineness Modulus	5.13
Specific gravity	2.65
Water Absorption	0.5%
Bulk density	1520 kg/m^3
Crushing value	34.23%

Fine Aggregates (FA)

River sand was procured from the nearest barrow pits. According to IS 2386-1968 part-3 and IS: 383- 2016 [9], [10] physical properties are determined and listed in table 2.

Table 2: Properties of Fine aggregates

Features	Obtained values
Fineness Modulus	3.14
Specific gravity	2.59
Moisture content	1.2%
Bulk density	1600 kg/m^3

Cement

OPC 53 grade Cement was used for this study. It was tested according to IS-4031-1988 and IS 269-1976 [11][12].The characteristics of cement are determined and listed below in table 3.

Table 3: Properties of cement

Features	Obtained values
Fineness of cement	8%
Specific gravity	3.12
Standard consistency	28%
Initial setting time	40 min
Final setting time	250 mins
28 days compressive strength	56.5 MPa

Copper slag [CS]

Copper slag resembles river sand in its physical characteristics. It is black in colour with irregular grains, with glassy surface. It is by-product or marginal material produced during the course of copper smelting and refinement. Tests were conducted as per IS code 2386-1968 part-3 and IS: 383- 2016 [9], [10] are listed in table 4.

Table 4: Properties of Pulverized plastic

Features	Obtained values
Specific gravity	3.12
Fineness modulus	4.1
Bulk density	2030 kg/m^3
Moisture content	0.8%

Water

Water aids in lubrication of ingredients, hydration process and curing. The portable water satisfying the requirements of IS:456 – 2000 is used for this research [13].

3. EXPERIMENTATION

Concrete of M-35 grade was designed according to IS: 10262- 2019 [14] with 0.45 water-cement ratio for moderate exposure condition. Using drum mixer dry mixing was done, followed by the addition of water containing super plasticizer of 2% by weight of water to attain a slump of 100mm. Copper slag was replaced for river sand at 15, 30 and 45% by weight. The details of the mix proportions and replacement levels of fine aggregates are as represented in the Table 5.

Using slump cone test fresh concrete workability was determined according to IS: 1199 – 1959 [15]. It was filled in 3 layers into the cube, cylinder and beam moulds according to IS: 516 -1959 & IS: 10086 -1982 [16], [17].

After 24 hours demoulding was carried out and the specimens were placed in water bath till the date of testing. According to IS: 516-1959 [16] compression, split tensile and flexural strength of the specimens were determined. To check porosity of the specimens, sorptivity test was conducted.

Concrete specimen of 7.5cm height and 7.5cm diameter was used to determine the sorptivity. Post 28 days of water bath curing, samples were dried under sunlight and dry weight was noted. Specimens were submerged in water only for 5cm height from bottom portion of sample. Specimens were placed on the 3cm height metal piece for the free movement of water. Specimens were placed out of water after 24 hours and the increase in weight was noted. Sorptivity of the specimen was determined using following formula.

$$\text{Sorptivity} = (q / a) \times (1 / \sqrt{T})$$

q = (Saturated weight) – (dry weight)
a = area of exposed surface
T = Time

Table 5: Mix Proportion of Trial Mixes

Mix Name	Copper slag (%)	Cement (kg/m^3)	C.A (kg/m^3)	F.A (kg/m^3)	CS (kg/m^3)	SP [2%]	Water (ltrs)	Workability (mm)
Mix 1	0	372.4	1180.33	677.51	0	7.44	167.58	100
Mix 2	15			575.88	101.62			102
Mix 3	30			474.25	203.25			106
Mix 4	45			372.63	304.57			108

4. RESULTS AND DISCUSSIONS

A. Compression strength test

Compression strength of concrete increased with age and the mix containing 45% copper slag depicted maximum strength at 28 days. Replacing river sand by copper slag increased the workability as copper slag will absorb minimum water. By increased availability of water, make the matrix to occupy the voids due to vibratory compaction making it more sturdy. Compression strength of various trial mixes are represented in figure 1.

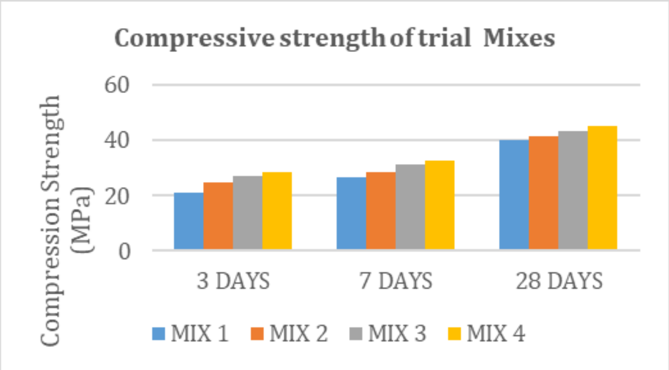

Fig 1: Compression strength of trial mixes

B. Split tensile strength

Split tensile strength was determined using cylindrical specimens. It was proportional to compressive strength. At 45% replacement of river sand by copper slag, maximum strength is achieved at 28 days. Figure 2 represents the improvements of split tensile strength of concrete specimens at corresponding ages and replacement levels.

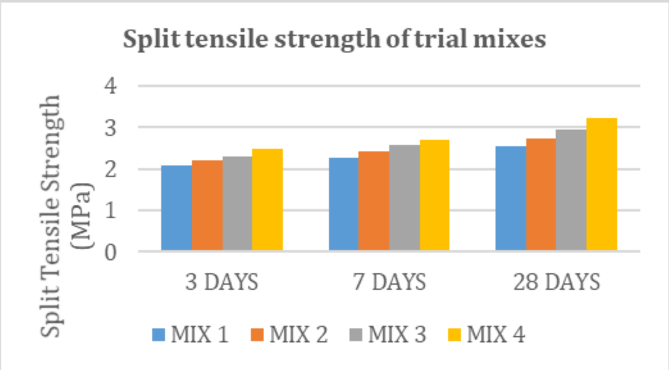

Fig 2: Split tensile strength of trial mixes

C. Flexural strength

Flexural strength was determined by subjecting the beam specimens to two-point loading at 28 days of age. Specimens having 45% of copper slag as fine aggregates exhibited maximum flexural strength as represented in figure 3.

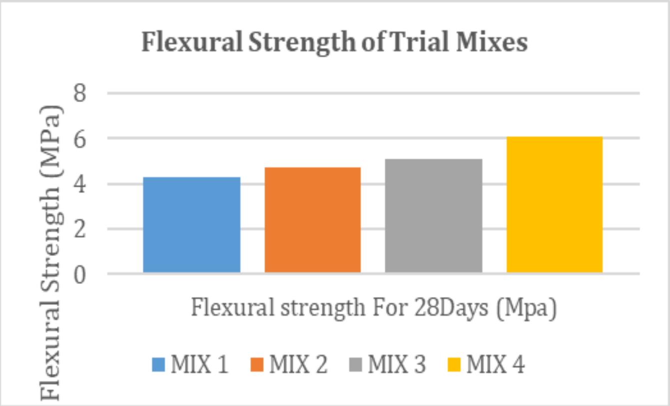

Fig 3: Flexural strength of trial mixes

D. Sorptivity test

Sorptivity of the material depict porous nature of the material. More the sorptivity, more voids in the matrix. From the figure 4, it can be observed that, sorptivity is maximum for the mix containing 30% of copper slag as fine aggregates. The concrete with 45% of copper slag would exhibit better durability over mix containing 30% of copper slag.

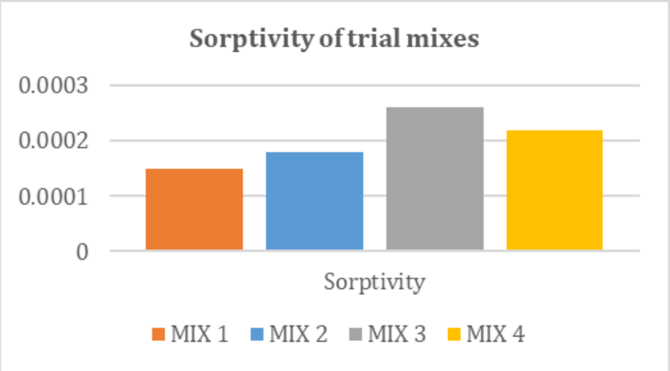

Fig 4: Sorptivity of trial mixes

5. CONCLUSIONS

1. Copper slag is smooth and shiny. Hence, workability enhances with increased replacement levels.
2. Compression, split tensile and flexural strength is maximum at 45% replacement.
3. Sorptivity values remains lesser at 45% than 30% replacement.

Hence the mix containing 45% of copper slag can be considered as the robust and durable mix. Environmental issues arising due to land filling activities can be suppressed by incorporating industrial by-product like copper slag in concrete. By replacing copper slag instead of conventional fine aggregate upto 45% optimum strength and durability can be expected along with conservation natural resources. Thus, it can be considered as an eco-friendly concrete.

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