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Experimental Study on Glass Fibre Reinforced Concrete with Partial Replacement of Copper Slag by Fine Aggregate

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Abstract: **Now a day we are facing most difficult protection problems related to environment. Many things which are invented for our luxurious life are responsible for polluting environment due to improper waste management technique. To reduce this issue to add or replace the concrete material by fibers or some other waste materials in concrete, In the Experimental program involves the study of flexural behavior of glass fibre reinforced concrete beam with copper slag as a partial replacement of fine aggregate. The parameters of the study included by replacing the fine aggregate by copper slag with 50%, 60%, 70% and by varying the volume fraction of glass fibre from 0 to 0.1% with an increment of 0.025%. The grade of concrete is M35. The specimens were cured for 7 and 28 days. The basic properties such as compressive strength, split tensile strength, flexural strength and flexural behavior of beams are studied. Based upon the results obtained it was concluded that, the replacement of copper slag is possible up to 60% with intrusion of glass fibre.**

Key words: copper slag, replacement, strength, glass fibre, Ordinary Portland cement, Compressive strength, Split tensile strength and Flexural strength.

I. INTRODUCTION:

Concrete is used as the basic materials for the construction works. In order to reduce dependence on natural aggregate, artificial aggregate generated from industrial waste provide an alternative for construction industry. The use of waste materials saves natural resources, cost, dumping spaces and it helps to maintain a clean environment.

The waste materials and by-products are; Quarry dust, copper slag. Copper slag is one of the by-products of smelting and refining process done during the extraction of copper. Copper slag is an industrial by-product obtained during the matte smelting and refining of copper. The density of copper slag is relatively higher since it has a higher composition of Iron oxide. So for many researchers found out that in the plain cement concretes, the replacements of copper slag is up to 40 to 50% by natural sand have better performance.

The strength and mechanical qualities of concrete is mainly depended on structure improvement, paste transport and aggregate through adding various compositions. Silica is one of the most important components in concrete micro-structure quality improvement. Therefore, wide researches are performed over pozolana adding on concretes along recent years.

The physical and mechanical properties of granulated copper slag shows that it can be used to make products like coarse and fine aggregates, cement, fill, ballast, roofing granules, glass, tiles etc.,

In this paper the effect of fibre when added in concrete was investigated. The percentage of copper slag replaced in fine aggregate varied from 50%, 60 %, 70% and their mechanical properties were studied. From the test results, the optimum value of replacement of copper slag with glass fibre was noted. With the optimum percentage of copper slag with glass fibre, the concrete beam specimen was casted and their flexural strength, load-deflection curve, ductility were studied.

II. MATERIALS USED

The ingredients of concrete consist of Cement, fine aggregate, coarse aggregate and water. In this work we used waste copper slag as a partial replacement for fine aggregate and it act as a filler material in concrete. Also add glass fibres which have changed its mechanical properties.

The experimental program included first the preliminary investigation on the materials used in the study, i.e., ingredients of concrete. The requirement which forms the basis of selection and proportioning of mix ingredients are:

A. Cement

The cement can be described as a material with adhesive and cohesive properties, which is capable of binding mineral fragment into compact mass. There are several types of cements available in market. Among which ordinary Portland cement (OPC) is most well-known. The 53 grade Ordinary Portland cement conforming to IS 12269:1987 was used in this project.

a) Specific gravity = 3.2
b) Consistency = 32%
c) Fineness = 2.1%.

B. Fine aggregate

A fine aggregate is increase the flowing ability and segregation resistance when used at a suitable amount. Aggregate which is passed through 4.75 IS Sieve and retained on 75micron (0.075mm) IS Sieve is termed as fine aggregate. The sand increases the volume of concrete and thus makes it cheaper. It fills the voids in concrete and gives density to concrete. It makes the mass homogeneous and improves the

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strength of concrete. In this project, the natural river sand conforming to IS: 383-1970 was used as fine aggregate
a) Specific gravity = 2.66
b) Fineness modulus = 3.09.
c) Moisture Content = 2.4%

C. Coarse aggregate

The size of aggregate bigger than 4.75mm is considered as coarse aggregate. It should be hard, strong, dense, durable, clean, and free from clay or loamy admixtures or quarry refuse or vegetable matter. The pieces of aggregates should be cubical, or rounded shaped. Coarse aggregates containing flat, elongated or flaky pieces or mica should be rejected. The grading of coarse aggregates should be as per the specifications of IS 383-1970. In this project 20mm nominal size of aggregate was used.
a) Specific Gravity = 2.81
b) Fineness Modulus = 6.04
c) Bulk Density = 1633Kg/m^3

D. Water

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be taken very carefully. Water used should be free from impurities. Sea water shall not be used.

E. Copper slag

Copper slag is a by-product obtained during the production of copper. The slag is a black glassy and granular in nature and has a similar particle size range like sand which can be used as a replacement of sand. Copper slag used in this work was brought from Sterlite industries (India) Ltd, Tuticorin.

Figure 1 copper slag

F. Glass fibre

Glass fibres used are of Cem-FIL Anti Crack – HD with modulus of elasticity 72 GPa, Filament diameter 14 microns, specific gravity 2.68, length 12mm and having the aspect ratio of 857.1. The number of fibers per kg is 212 million fiber. It was purchased in Leo Enterprises, Nagercoil.

a. Types of Glass Fibers

A-glass - Close to normal glass
C-glass - Resist chemical attack
E-glass -Insulation to electricity
AE-glass - Alkali Resistance
S-glass - High strength fiber

Figure 2 Glass Fibre

Table 1 Properties of fibre

Length	12mm
Filament	14microns
Aspect Ratio	857.1
Modulus of Elasticity	72Gpa
Specific Gravity	2.71
Density	2680kg/m^3
Alkali Resistance	High

III. METHODOLOGY

The study aims to investigate the strength related properties of concrete of M35 grade made using copper slag and addition of glass fibre. The proportions of ingredients of the control concrete of grade M35 had to be determined by mix design as per IS code. The specimens were casted by replacements of fine aggregate with copper slag by 50%, 60%, 70% and by varying the volume fraction of glass fibre from 0 to 0.1% with an increment of 0.025%. Then the specimens were cured for 7 days and 28 days. The various tests such as compression test, split tensile test, and flexural tests were carried out on the specimens.

IV. EXPERIMENTAL WORK

In this experimentation, an attempt has been made to find out the concrete strength and replaced concrete strength for M35 grade of concrete. The properties of concrete materials and concrete strength were determined.

Mix design carried for M35 grade of concrete by IS 10262-2009 yielded mix proportions of 1:1.452:2.774 with water cement ratio of 0.45. Specimens were prepared according to the mix proportion and by replacing sand with copper slag in different proportions and adding glass fibre to decrease the bleeding..

A. MIX PROPORTION OF CONCRETE GRADE

As per IS 10262: 2009, mix design for M35 grade concrete is carried out**:**

Table 2. Mix Design for M35 Conventional

Specification	Cement kg/m^3)	Water (kg/m^3)	Aggregate (kg/m^3)	
			Fine	Coarse
Quantity	413	0.45	674	1185
Ratio	1	0.45	1.63	2.86

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a. Description of Specimen

The number of specimens casted was as per the below-mentioned details. The size of cube is 150x150x150mm, size of cylinder Dia=150mm and Height=300mm, size of prism 100x100x500mm.

Table 3. Description of Specimens

S.No	Name Of Specimen	Percentage Addition (%)		Specimen		
		Copper slag	Glass fibre	Cube	Cylinder	prism
1	CC	0	0	6	3	3
2	A	50	0	6	3	3
3	A1		0.025	6	3	3
4	A2		0.05	6	3	3
5	A3		0.075	6	3	3
6	A4		0.1	6	3	3
7	B	60	0	6	3	3
8	B1		0.025	6	3	3
9	B2		0.05	6	3	3
10	B3		0.075	6	3	3
11	B4		0.1	6	3	3
12	C	70	0	6	3	3
13	C1		0.025	6	3	3
14	C2		0.05	6	3	3
15	C3		0.075	6	3	3
16	C4		0.1	6	3	3

V. RESULTS AND DISCUSSIONS

A. FRESH CONCRETE

a. Workability

Slump test is used to determine the workability of fresh concrete**.** Slump test as per IS: 1199 - 1959 is followed. The obtained slump value for normal concrete is 50 mm. This indicates medium workability

B. HARDENED CONCRETE

a. Compressive Strength

The compressive strength test for cubes was conducted in compression testing machine as per IS 516 : 1964. The cubes were tested in compressive testing machine at the rate of 140 kg/cm^2/min. and the ultimate loads were recorded.

Compression Strength (N/mm^2) = $\frac{P}{A}$

Where,

P - Ultimate load (N)

A – Area of the cube (mm^2)

Figure 3. Experimental setup of compression test

Graph shows the average Compressive strength of concrete for 7 and 28 days.

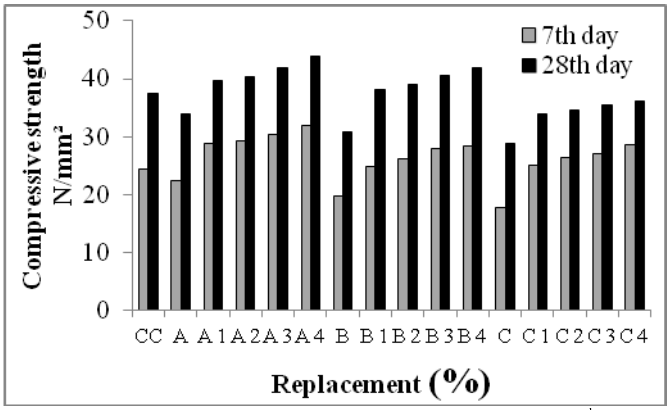

Figure 4 Variation of compressive strength of concrete for7 & 28th day

A, B, C cube shows 9.625%, 17.914%, 22.99% decrease in compressive strength when compared to CC cube. This is due to increases free water content in the mixes. The excessive free water content in the mixes with copper slag content causes the bleeding and segregation in concrete. Therefore, it leads reduction in the strength. A reduction in bleeding is observed by addition of glass fibre in concrete mix. A reduction in bleeding improves the surface integrity of concrete, improves its homogeneity and reduces the probability of cracks. A1, A2, A3, A4 cube shows 5.79%, 7.425%, 10.74%, 14.611% increase in compressive strength when compared to CC cube and it shows 14.86%, 16.33%, 19.33%, 20.83% increase in compressive strength when compared to A cube.B1, B2, B3, B4 cube shows 1.914%, 4.347%, 7.995%, 10.633% increase in compressive strength when compared to CC cube and it shows 19.48%, 21.48%, 24.47%, 26.64% increase in compressive strength when compared to B cube.C1, C2, C3, C4 cube shows 9.35%, 7.75%, 5.34%, 3.20% decrease in compressive strength when compared to CC cube and it shows 15.04%, 16.52%, 18.64%, 20.44% increase in compressive strength when compared to C cube.

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b. Split Tensile Strength

The split tensile strength test for cylinders was carried out as per IS 516 : 1964. This test was carried out by placing a cylinder specimen horizontally between the loading surfaces of a universal testing machine and the load was applied until failure of the cylinder along the vertical diameter.

Split tensile strength, fcr (N/mm^2) = $\frac{2P}{\pi lD}$

Where,

P = Ultimate load (kN)
L = Length of cylinder (mm)
D = Diameter of cylinder (mm)

Figure 5. Experimental setup of Split Tensile

The graphical representation of the variation of average split-tensile strength at 28^{th} day is shown in figure 6.

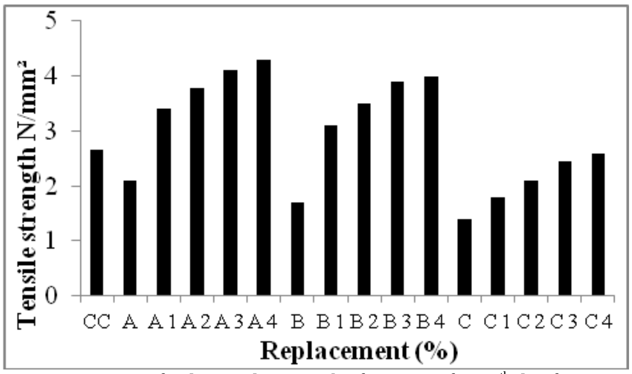

Figure 6 Variation of split tensile strength of concrete for 28^{th} day for various specimens

From the test results, it was observed that the tensile strength of concrete showed similar behavior to the compressive strength. A, B, C cylinder shows 20.75%, 35.84%, 47.16% decrease in tensile strength when compared to CC cylinder.A1, A2, A3, A4 cylinder shows 22.05%, 29.85%, 35.36%, 38.37% increase in tensile strength when compared to CC cylinder and it shows 38.23%, 44.44%, 48.78%, 51.16% increase in tensile strength when compared to A cylinder.B1, B2, B3, B4 cylinder shows 14.51 %, 24.28%, 32.05%, 33.75% increase in tensile strength when compared to CC cylinder and it shows 45.16%, 51.42%, 56.41%, 57.5% increase in tensile strength when compared to B cylinder.C1, C2, C3, C4 cylinder shows 32.83%, 20.75%, 7.54%, 2.64% decrease in tensile strength when compared to CC cylinder and it shows 21.34%, 33.33%, 42.85%, 45.73% increase in tensile strength when compared to C cylinder.

c. Modulus of Rupture

Flexural strength is the ability of a beam or slab to resist failure in bending. It is measured by loading un-reinforced concrete beams with a span three times the depth. The flexural strength is expressed as “Modulus of Rupture” (MR) in N/mm^2. The modulus of rupture is calculated as follows

$$F = \frac{P \times l}{b \times d^2} \quad \text{for ‘a’ greater than 133 mm}$$

$$F = \frac{3 \times P \times l}{b \times d^2} \quad \text{for ‘a’ between 110 mm to 133 mm}$$

Where,

F = Flexural Strength (N/mm^2)
P = Ultimate load (kN)
L = span length (mm)
b = average width (mm)
d = average depth (mm)

Figure 7. Experimental Setup of Flexural Test

A, B, C prism shows 8.97%, 17.94%, 24.35% decrease in flexural strength when compared to CC prism.A1, A2, A3, A4 prism shows 10.34%, 17.40%, 23.52%, 31.57% increase in compressive strength when compared to CC prism and it shows 18.39%, 27.55%, 30.39%, 37.719% increase in flexural strength when compared to A prism.B1, B2, B3, B4 prism shows 3.703 %, 10.34%, 15.21%, 25.71% increase in flexural strength when compared to CC prism and it shows 20.98%, 26.43%, 30.434%, 39.04% increase in flexural strength when compared to B prism.C1, C2, C3, C4 prism shows 20.51%, 15.76%, 6.41%, 1.28% decrease in flexural strength when compared to CC prism and it shows 4.83%, 10.1%, 19.17%, 23.37% increase in flexural strength when compared to C prism.

The graphical representation of the variation of average flexural strength at 28^{th} days is shown in figure 4.3.

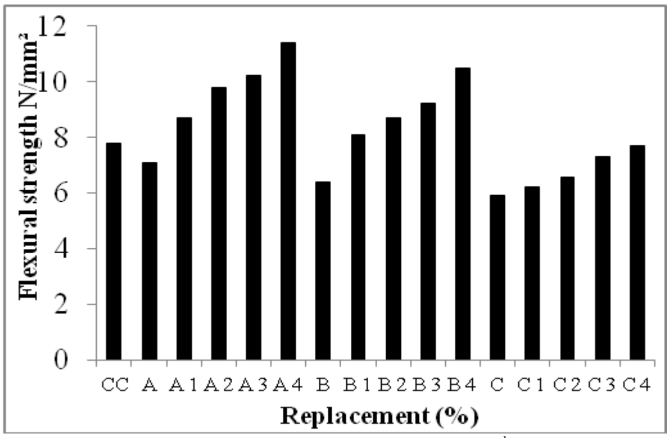

Figure 8 Variation of flexural strength of concrete for 28^{th} day for various specimens

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VI. EXPERIMENTAL INVESTIGATION FOR GLASS FIBRE REINFORCED CONCRETE

A. *Specimen Details*

Four numbers of reinforced concrete beams without and various percentage of copper slag were cast and tested. The span of the beam was 1500 mm and of size 150 mm x 300 mm**.** Out of the 4 specimens tested one specimen casted without copper slag and adding of glass fibre and another 3 specimen casted with 50%, 60% & 70% as replacement for fine aggregate. Specimens were tested at 28th day from the date of casting. Reinforcement details of the specimens tested are given in figure 9.

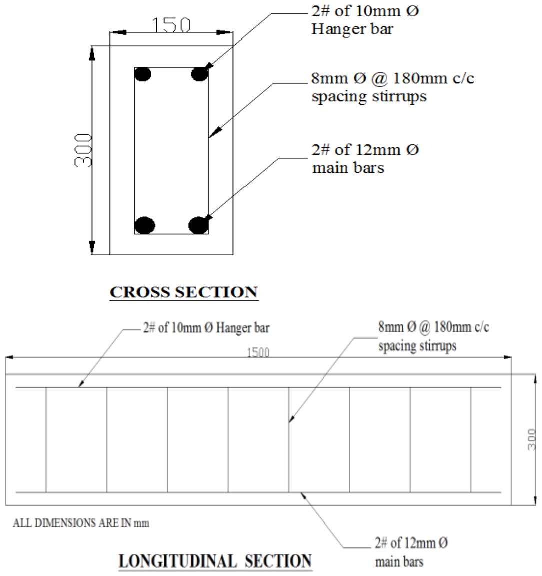

Figure 9.Cross section & Reinforcement Details of Beam

B. *Test setup*

The testing was carried out in a loading frame of 10T capacity. All the specimens were white washed in order to facilitate marking of cracks. Strain gauges of 20 mm were fixed to the reinforcement to measure the strain and LVDTs were used for measuring deflections at midspan. The beams were subjected to two-point loads under a load control mode. The development of cracks was observed and the crack widths were measured using a hand-held microscope with an optical magnification of X50 and a sensitivity of 0.02 mm. Figure 10 shows the arrangement of LVDT and Strain gauges in the experimental setup.

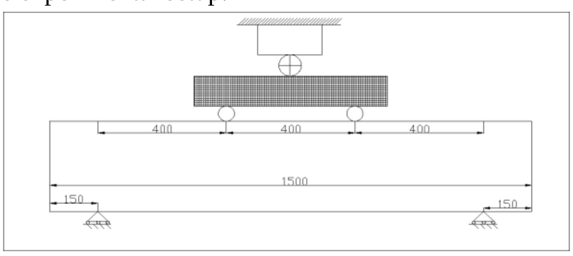

Figure 10 Test Setup

Figure 11. Experimental Load Setup

VII. RESULTS AND DISCUSSION

A. *Load- deflection curve*

The experimental load-deflection curves of the RC beams with 0%, 50% and 60% Copper Slag added with by varying the volume fraction of glass fibre 0.1%.The grade of concrete is M35. When tested at 28th day are shown in Figure 11. The average ultimate loads for beams at 28th day. Thus the ultimate loads for the Beams with 50%&60% copper slag is higher than that of the controlled beams at 28th day.

The deflection curve for the conventional concrete, copper slag 50% and copper slag 60% as shows in the figure 12

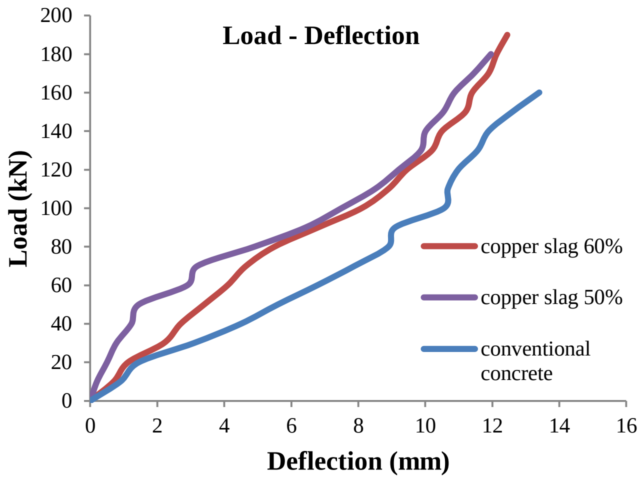

Figure 12. Load-Deflection curve of reinforced concrete

B. *Ductility Ratio*

Ductility is the ratio of the ultimate deformation to that at the first yielding of steel reinforcement. Table.4 shows the ductility ratio for different specimens, and it can be seen that, ductility ratio decreases as the loading rate increases for the specimens containing copper slag

Table 4: Determination of Ductility Ratio

S.No.	Specimen	Yield Deflection	Ultimate Deflection	Ductility Ratio
1	CC	5.6	13.4	2.39
2	CS-50	4.9	11.96	2.28
3	CS-60	5.5	12.45	2.26

VIII. CONCLUSION

- ✓ From the test results, it was found that the compressive strength, split tensile strength and flexural strength increases while adding 50% and 60% replacement of fine aggregate by copper slag with glass fibre.
- ✓ The optimum percentage of fibre to be added was found to be 0.1%.

- ✓ Adding 50%, 60%, 70% replacement of fine aggregate by copper slag the strength decreased. This is due to increases free water content in the mixes. The excessive free water content in the mixes with copper slag content causes the bleeding and segregation in concrete.
- ✓ With the addition of glass fibre at 50% and 60% of fine aggregate by copper slag the strength increased, because fibre reduce the permeability of concrete and thus bleeding of concrete get reduced. A reduction in bleeding improves the surface integrity of concrete, improves its homogeneity and reduces the probability of cracks.
- ✓ But for 70% replacement of fine aggregate by copper slag with glass fibre, the strength gets decreased when compared to conventional concrete. This is due to high workability of concrete.
- ✓ Flexural strength of beam is increased due to high toughness of Copper slag.
- ✓ The Glass fibre increases the strength of concrete with lower fibre dosage and it will be improves crack control and preserves post cracking due to the properties of glass fibre.
- ✓ The ultimate load carrying capacity of beam with copper slag 50% and glass fibre 0.1% beam increases by 15.7% than the controlled beam when tested at 28 days.
- ✓ Replacement of copper slag in fine aggregates replacement reduces the cost of making concrete and it provides additional environmental as well as technical benefits for all related industries.
- ✓ Based upon the results obtained it was concluded that, the replacement of copper slag by fine aggregates is possible up to 60% with intrusion of glass fibre.

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