

Effect of Replacing Copper Slag as Fine Aggregate and Mangalore Tile as Coarse Aggregate on Properties of Concrete

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ABSTRACT: An experiment was conducted to investigate the effect of replacing copper slag as fine aggregate and Mangalore tile as coarse aggregate on properties of concrete and results have been presented in this paper. M30 Grade Concrete was used. Proportions of Mangalore tile replacement vary in the range of 0, 20, 30 and 40% and that of copper slag replacement varies in the range of 0, 20, 40 & 60% in concrete. Strength properties such as Compressive Strength, Split Tensile Strength, Flexural Strength were evaluated. Test results shows that the strength properties of concrete has improved having copper slag as a partial replacement of fine aggregate and Mangalore tile as partial replacement of coarse aggregate (up to 40% ,20 % respectively) in concrete.

KEYWORDS: Copper Slag, Mangalore Tile.

I. INTRODUCTION

Concrete is one of the major construction material being used worldwide. Aggregate, besides cement and water, forms one of the main constituent materials of concrete since it occupies nearly 55%–80% of concrete volume. The aggregate types utilized are either coarse aggregates (with particle size more than 4.75 mm) or fine aggregates (with particle size less than 4.75 mm). Aggregates which are used in concrete are obtained either from natural sources or by crushing large size rocks. The rapid increase in the natural aggregates consumption every year due to the increase in the construction industry worldwide means that the aggregate reserves are being depleted rapidly, large consumption of natural aggregates will cause destruction of the environment. Therefore there is an urgent need to find and supply alternative substitutes for natural aggregates by exploring the possibility of utilization of industrial by-products and waste materials in making concrete. This will lead to sustainable concrete design and greener environment.

Copper slag is one of the materials that are considered as a waste material which could have a promising future in construction industry as partial or full substitute of either cement or aggregates. It is a by-product obtained during the matte smelting and refining of copper. To produce every ton of copper, approximately 2.2–3.0 tons copper slag is generated as a by-product material. It is producing Copper slag during the manufacture of copper metal. Currently, about 2600 tons of Copper slag is produced per day and a total accumulation of around 1.5 million tons. If we are able to use the copper slag in place of natural sand then we can successively obtain a material to replace the sand, which is eco-friendly and cost effective. Hence there is a growing need to find the alternative solution for the slag management. Mangalore was the birth place of tiles and the tiles were used all over India hence were known as Mangalore tiles. It was first introduced in India by a German missionary and these are fired clay tiles. The tiles produced by the factory were in great demand throughout the Indian subcontinent and East Africa. Abundant deposits of clay. Hence broken

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tiles are available in plenty and free of cost and can be utilized as a coarse aggregate. In the present study, it is proposed to study the effect of addition of copper slag mixed with natural sand and Mangalore tile waste as coarse aggregate in concrete.

II. RELATED WORK

From various literatures, it was observed that

- Workability and density of concrete increases as the percentage of copper slag increases.
- Maximum compressive strength is obtained at 40 % replacement of copper slag.
- At 100 % replacement of copper slag the strength is found to be reduced.
- Optimum percentage of roof tile is 20% beyond this limit the strength become reduced.
- Copper slag and tiles powder can be used as a replacement material for fine aggregate.

III. EXPERIMENTAL DETAILS

3.1 Objective

Main objectives of the study are

- To investigate the potential of copper slag as fine aggregate in concrete.
- To investigate the potential of Mangalore tile waste as coarse aggregate in concrete.
- To optimize the percentage of replacement of fine aggregate and coarse aggregate.
- To study the effect of both copper slag and Mangalore tile on the properties of concrete

3.2 Materials

3.2.1 Cement

53 Grade OPC having specific gravity of 3.15, normal consistency of 32% was used. As per IS 4031-1988, various tests were conducted to check the quality of cement and confirmed to specifications of 12269-1987.

3.2.2 Fine Aggregate

M sand having the specific gravity of 2.65 and fineness modulus 4 was used. The Bulk Density in loose state and compacted state were found to be 1.28 kg/litre and 1.75kg/litre respectively. The water absorption was 2.3%.

3.2.3 Coarse Aggregate

20mm size angular crushed metal having specific gravity of 2.67 and fineness modulus of 3.08 was used. Bulk Density in loose state and compacted state were found to be 1.49 kg/litre and 1.69kg/litre respectively. The water absorption was 0.349%.

3.2.4 Mangalore Tile

Mangalore Tile with specific gravity 2.41 and fineness modulus 4.46 was used. The water absorption was 14.33%. Fig.2.1 shows the picture of Mangalore tile used in the study.



Figure 2.1 Mangalore Tile.

3.2.5 Copper Slag

Copper Slag with sp. gravity 3.49 and fineness modulus 4.79 was used. Bulk Density in loose state and compacted state was found to be 1.89 kg/litre and 2.02 kg/litre respectively. The water absorption was 0.14%. As per the chemical

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analysis of Copper Slag, Silica content in Copper Slag was found to be 25.84%. Fig.2.2 shows the picture of copper slag used in the study.



Figure 2.2 Copper Slag

3.3 Mix proportion

Table 2.1 Mix details for M₃₀ mix for 1 m³
(Target Mean Strength = 38.25 MPa)

Water	Cement	Fine Aggregate	Coarse Aggregate
160	400	671	1177
0.4	1	1.67	2.92

3.4 Specimen Details

Table 2.2 Specimen details

SPECIMEN	SIZE(mm)
Cube	150
Cylinder	150 diameter, 300 height
Beam	100x100x500

IV. EXPERIMENTAL METHODOLOGY

The evaluation of copper slag and Mangalore tile as replacement material for fine aggregate and coarse aggregate begins with concrete testing. Concrete contains water, cement, fine aggregate and coarse aggregate. With the control concrete, ie, 20%, 40% and 60% of fine aggregate is replaced with copper slag and 20%, 30% and 40% of coarse aggregate with Mangalore tile. Combination of 20% Mangalore tile with 20%, 40% and 60% copper slag, combination of 30% Mangalore tile with 20%, 40% and 60% copper slag and combination of 40% Mangalore tile with 20%, 40% and 60% copper slag also conducted in this work.

The results obtained are compared with those of control concrete. The cube, cylinder and beam specimens were casted for each replacement. After about 24 h the specimens were de-moulded and water curing was continued till the respective specimens were tested after 7, 28 days for compressive strength, split tensile strength and flexural strength tests.

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V. TESTS CONDUCTED

5.1 Compressive strength

The cube strength was evaluated according to IS 516-1959(Reaffirmed 2004).The test was conducted on a 2000 kN compression testing machine. The ultimate load divided by the area gives the cube strength.

5.2 Split tensile strength

Split tensile strength was obtained by testing cylindrical specimen by applying load through its axis in compression testing machine of capacity 2000 kN as per IS 5816:1999.The split tensile strength was computed with Eqn.(3.1).

$$f_{ct} = \frac{2P}{\pi DL} \text{ ----- (3.1)}$$

Where, f_{ct} = Split tensile strength in N/mm²

P = Maximum Load in N

D = Diameter of the specimen in mm

L = Length of the specimen in mm

5.3 Flexural strength

The flexural tensile strength or modulus of rupture is determined by testing standard beam specimens of 10x10x50 cm over a span of 40 cm under symmetrical two-point loading. The flexural strength is determined according to IS: 515-1975.For this test standard compression testing machine of 1000 kN (100 T) capacity was used. The two point loading were placed at a distance of 133 mm and bottom was placed at an effective span of 400 mm as per IS 516-1959.The load was applied without shock and increasing continuously at a rate of 1800 N/min.The flexural strength of the specimen shall be expressed as the modulus of rupture F_b .The modulus of rupture was calculated as follows.

$$F_b = (PxL) / (bx d^2) \text{ ----- (3.2)}$$

Where, F_b = Flexural strength of concrete in (MPa)

P = Failure load (in N)

L = Effective span of the beam (400 mm)

b = Breadth of the beam (100 mm)

d = depth of the beam (100 mm)

The equation is used when the distance between the lines of fracture and nearer support greater than 133 mm.

$$F_b = (3xPx a) / (bx d^2) \text{ ----- (3.3)}$$

The equation is used when the distance between the line of fracture and the support less than 133 mm but greater than 110 mm.

VI. EXPERIMENTAL RESULTS

6.1 compressive Strength results

From the results obtained, it was observed that compressive strength of concrete using copper slag as fine aggregate and Mangalore tile as coarse aggregate is satisfactory up to 40 % and 20 % respectively. The compressive strength of concrete increased as the percentage of copper slag increased and decreased as the percentage of Mangalore tile increased. Maximum compressive strength is obtained at a combination of 20% Mangalore tile and 40% Copper Slag. The variation of compressive strength is shown in table 5.1 and graphical representation of compressive strength is shown in fig. 5.1 for 28th day.

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Table 5.1 Results of Compressive Strength.

CS \ MT	0 %		20 %		40 %		60 %	
	Compressive strength (N/mm ²)							
	7 th day	28 th day	7 th day	28 th day	7 th day	28 th day	7 th day	28 th day
0 %	38.88	42.44	37.70	49.78	39.55	52.44	36.46	47.75
20 %	34.51	40.86	45.66	51.14	47.29	53.55	43.66	50.21
30 %	32.54	38.59	41.78	46.75	43.56	48.88	38.44	45.43
40 %	29.03	38.33	32.66	42.36	33.69	44.21	32.66	40.66

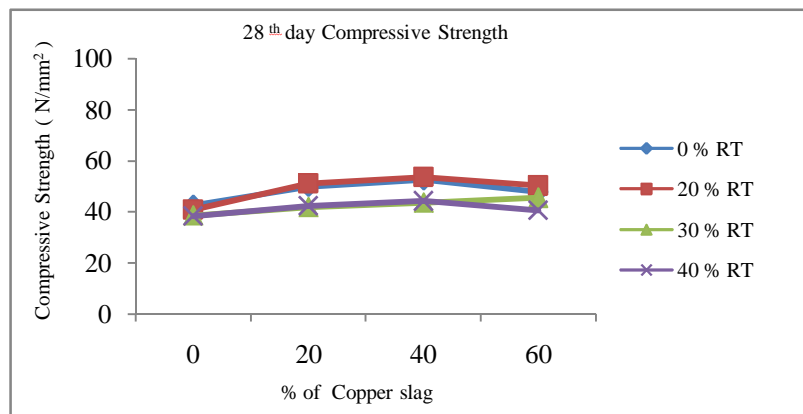


Figure 5.1 28th day Compressive Strength

6.2 Split Tensile Strength

From the results it was observed that, as the percentage of copper slag increased tensile strength of concrete is increased, tensile strength is decreased as the percentage of Mangalore tile increased. The variation of tensile strength is shown in table 5.3 and graphical representation of tensile strength is shown in fig. 5.2 for 28th day.

Table 5.2 Results of Split Tensile Strength.

CS \ MT	0 %		20 %		40 %		60 %	
	Split Tensile Strength (N/mm ²)							
	7 th day	28 th day	7 th day	28 th day	7 th day	28 th day	7 th day	28 th day
0 %	4.93	5.39	5.29	5.65	5.46	5.81	5.51	5.94
20 %	4.71	5.38	4.73	5.39	4.88	5.60	4.95	5.65
30 %	4.67	5.11	4.70	5.23	4.75	5.34	4.83	5.45
40 %	4.62	4.98	4.69	5.08	4.74	5.16	4.81	5.26

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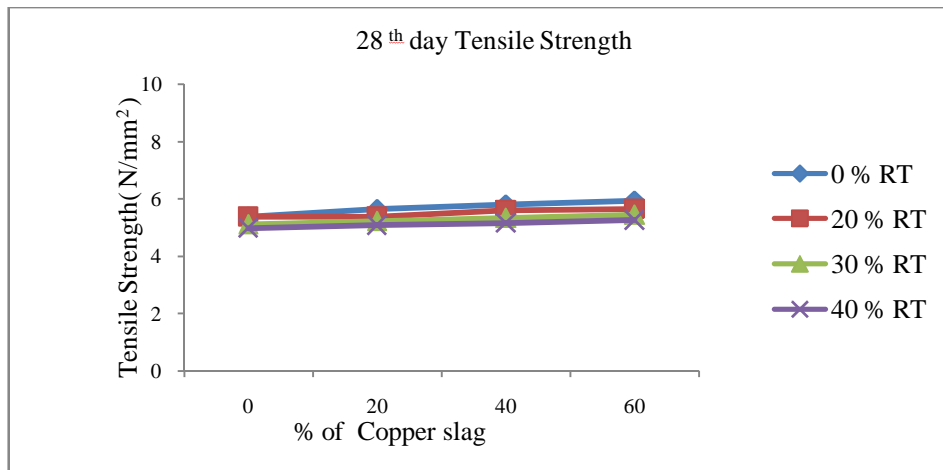


Figure 5.2 28th day Tensile Strength

6.3 Flexural Strength

From the results it was observed that, as the percentage of Mangalore tile increased flexural strength of concrete is decreased. Up to 20% Copper slag flexural strength increased and then decreased. The variation of flexural strength is shown in table 5.3 and graphical representation of flexural strength is shown in fig. 5.3 for 28th day.

Table 5.3 Results of Flexural Strength.

CS \ MT	0 %		20 %		40 %		60 %	
	Flexural Strength (N/mm ²)							
	7 th day	28 th day	7 th day	28 th day	7 th day	28 th day	7 th day	28 th day
0 %	6.25	6.58	6.75	7.58	5.91	6.66	5.83	6.50
20 %	4.50	6.00	5.75	7.61	5.00	6.50	4.75	6.08
30 %	4.00	5.55	4.58	6.75	4.00	6.05	3.75	5.83
40 %	3.46	5.16	4.50	5.83	3.50	5.60	3.00	5.58

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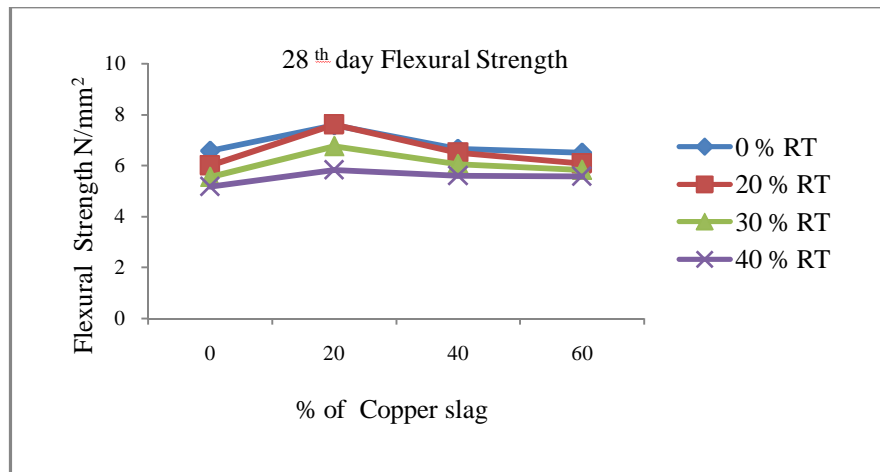


Figure 5.3 28th day Flexural Strength

VII. CONCLUSION

The conclusions obtained from the study are as follows.

- Compressive strength is greater than that of control mix in all replacement of fine aggregate by copper slag, so it can be used as a fine aggregate in concrete.
- In the replacement of coarse aggregate by Mangalore Tile, all replacement shows greater compressive strength than that of target strength, so it can be used as a coarse aggregate in concrete.
- The optimum compressive strength obtained at 40% replacement of fine aggregate by copper slag and 20 % replacement of Mangalore tile as coarse aggregate.
- Tensile strength of concrete is increased as the percentage of copper slag increased and decreased as the percentage of Mangalore tile increased.
- Flexural strength of concrete is decreased as the percentage of Mangalore tile increased.
- The optimum flexural strength obtained at 20% replacement of fine aggregate by copper slag and then decreases.

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