A Study on Concrete Mix Design of Partial and Full Replacement of Copper Slag with Fine Aggregate

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Abstract: **- Sand has by now become the most widely consumed natural resource on the planet after water and air. The annual world consumption of sand is estimated to be 40 billion tons, with a respective trade volume of 70 billion dollars. But nowhere is the struggle for sand more ferocious than in India, Hence an immediate replacement for River sand is necessitated, In this fast growing world where the industries are growing at faster rate especially metallic industries producing copper and iron where their slags are the major waste products having high strength. Many researchers have already found it possible to use Copper slag as a concrete aggregate, because copper slag has similar particle size characteristics likely to that of sand. Hence the study focuses on the various percentage replacement of Copper Slag with Fine aggregate varying from 38% to 52% at interval of 2%, since replacement of 40% to 50% shows strength improvement. Complete and no replacement i.e., 100% and 0% were also taken into account. Mix design for each % replacement is calculated and Cubes were casted for 28 days curing period. Finally the specimens were Compression tested and % replacement with maximum increase in strength is identified.**

Key Words: **Copper slag, Mix Design, Compression Tested.**

I. INTRODUCTION

River sand is being used as Fine aggregate in concrete for centuries. In some regions, river sand has been excessively exploited, which has endangered the stability of river banks and the safety of bridges, and creates environmental problems. On the other hand, river sand is expensive due to excessive cost of. Seeking for river sand alternatives has become urgent.

Copper slag is granular material with high specific gravity. The use of copper slag in cement and concrete provides potential environmental as well as economic benefits for all related industries, Heavy metals in copper slag samples was tested by National Council for Cement and Building Materials, New Delhi as per the method given in ASTM D-5233-1995d. The results indicate that the leaching of heavy metals was well below the toxicity limits even under aggressive condition. Utilization of copper slag in applications such as Portland cement substitution and/or as aggregates has threefold advantages of eliminating the costs of dumping, reducing the cost of concrete, and minimizing air pollution problems.

In this work Copper slag is replaced with Fine aggregate in the ratios of 0%, 38%, 40%, 42%, 44%, 46%, 48%, 50%, 52% and 100% for curing periods of 28 days. The volumetric replacement of fine aggregate with copper slag is only considered while everything elsewhere was left unchanged.

II. MATERIELS

2.1 CEMENT

53 Grade (Ultra tech) ordinary Portland cement (OPC) having specific gravity of 3.094, fineness modulus of 4.62% was used. As per IS 4031-1988,

2.2 FINE AGGREGATE

The aggregate size is lesser than 4.75mm is considered as fine aggregate. The sand particles should be free from any clay or inorganic materials and found to be hard and durable. River sand having the specific gravity of 2.6 and fineness modulus 2.4 was used.

2.3 COARSE AGGREGATE:

Coarse aggregate differ in nature and shape depending on their extraction and production. Locally available Coarse aggregate of passing through 20mm sieve and retained on 4.75mm sieve were used for this study. 20mm size angular crushed granite metal having specific gravity of 2.6 was used.

2.4 WATER

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. It gives strength to cement and workability to the concrete. Drinking water is used for casting and curing of the concrete blocks.

2.5 COPPER SLAG

Copper slag is a by-product obtained during the smelting and refining of copper. Copper slag used in this work was brought from Sterlite Industries Ltd (SIL), Tuticorin, Tamil Nadu, India.

Fig. 1 a. Fine aggregate b. Copper Slag

TABLE 1: PHYSICAL PROPRTIES OF SAND &COPPER SLAG

Physical properties	Sand	Copper slag
Particle shape	Irregular	Irregular
Appearance	Brownish yellow	Black glassy
Specific gravity	2.61	3.91
Fineness modulus	3.14	3.47
Water absorption	1.3	0.16
Moisture content	0.43	0.1

TABLE 2: CHEMICAL PROPERTIES OF SAND & COPPER SLAG

Chemical properties	% Sand	% Copper slag
Sio_2	0.77	25.84
Fe_2O_3	0.36	68.29
Al_2O_3	0.11	0.22
Cao	54.71	0.15
Na_2O	0.15	0.58
K_2O	0.91	0.23
TiO_2	0.32	0.41

Since specific gravity is required in the calculation of Mix design, for each % replacement sample was taken and specific gravity test was conducted and results were obtained as shown in table 3

TABLE 3 : SPECIFIC GRAVITY TEST RESULTS FOR DIFFERENT % REPLACEMENT OF COPPER SLAG WITH FINE AGGREGATE

% Replacement		Specific Gravity
F.A	Copper Slag	
100%	0%	2.68
62%	38%	3.23
60%	40%	3.20
58%	42%	3.21
56%	44%	3.32
54%	46%	3.34
52%	48%	3.82
50%	50%	3.42
48%	52%	3.43
0%	100%	4.13

III. MIX DESIGN

All the samples were prepared using design mix. Design for the M20 grade concrete was done based on I.S code method. (AS PER IS: 10262-1982)

3.1 Target Strength for Mix Proportioning

$F_{ck}= f_{ck} + 1.65s$

Where, F_{ck} = Target average compressive strength at 28 days

F_{ck}= characteristics compressive strength at 28 days

s= standard deviation

From Table 1standard deviation, s=4.6N/mm^2

Therefore target strength =20+1.65*4.6

f_{ck} =27.59N/mm^2

3.2 SELECTION OF WATER CEMENT RATIO

From Table 5 of IS: 456-2000

Maximum water cement ratio= 0.50

Based on experience adopt water cement ratio as 0.48

0.4< 0.50, hence ok.

3.3 SELECTION OF WATER CONTENT

From Table-2, maximum water content=186 lit

(For 25mm-50mm slump range and for 20mm aggregate)

Estimated water content for 100mm slump= 186+3/100×186

=191.6lit

3.4 CALCULATION OF CEMENT CONTENT

Water content ratio=0.48

Cement content =191.6/0.48

=399.16kg/m^3

399.16>250kg /m^3, hence ok.

3.5 CALCULATION OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT

$$V=\left[W+\frac{c}{sc}+(\frac{1}{p})\frac{Fa}{sfa}\right]\times 1/1000$$

$$V=\left[W+\frac{C}{sc}+(\frac{1}{1-p})\frac{ca}{sca}\right]\times 1/1000$$

Where,

V = Absolute volume of fresh concrete, which is equal to gross volume minus the value of entrapped air.

W = Mass of water per m^3 of concrete.

C = Mass of cement per m^3 of concrete.

Sc = Specific gravity of cement.

Fa,ca = Total mass of fine aggregate and coarse aggregate per m^3 of concrete respectively.

Sfa, Sca = Specific gravity of saturated surface dry fine aggregate and coarse aggregate.

P = Ratio of F.A to total aggregate by absolute volume.

V= 1-2% =$0.98m^3$; W = 191.6 lit; C= $399.16kg/m^3$

Sc=3.15; P= 35%; Sfa = 2.68; Sca= 2.93

Applying for the formula we get the coarse and fine aggregate

FA=$523.49kg/m^3$; CA=$1367.14kg/m^3$

3.6 PERCENTAGE FOR MIX RATIO

Mix design for each % replacement of Copper slag with Fine aggregate was separately calculated. Each % replacement was tested along with the raw material testing. The Specific gravity for each % replacement which was obtained from the Specific gravity test was utilized for the calculation of their respective % replacements.

$$V= \left[W + \frac{c}{sc} + (\frac{1}{p})\frac{Fa}{sfa}\right] \times 1/1000$$

0%

$0.98 = (191.6+\frac{399.16}{3.15} +\frac{1}{0.295} \times \frac{Fa}{2.68})\times\frac{1}{1000}$

1:1.32:3.4

38% Replacement

$0.98=(191.6+\frac{399.16}{3.15} +\frac{1}{0.295} \times \frac{Fa}{3.23})\times\frac{1}{1000}$

1:1.57:3.4

40% Replacement

$0.98 = (191.6+\frac{399.16}{3.15} +\frac{1}{0.295} \times \frac{Fa}{3.20})\times\frac{1}{1000}$

1:1.56:3.4

42% Replacement

$0.98 = (191.6+\frac{399.16}{3.15} +\frac{1}{0.295} \times \frac{Fa}{3.21})\times\frac{1}{1000}$

1:1.57:3.4

44%Replacement

$0.98 = (191.6+\frac{399.16}{3.15} +\frac{1}{0.295} \times \frac{Fa}{3.32})\times\frac{1}{1000}$

1:1.62:3.4

46% Replacement

$0.98 = (191.6+\frac{399.16}{3.15} +\frac{1}{0.295} \times \frac{Fa}{3.342})\times\frac{1}{1000}$

1:1.63:3.4

48% Replacement

$0.98 = (191.6+\frac{399.16}{3.15} +\frac{1}{0.295} \times \frac{Fa}{3.382})\times\frac{1}{1000}$

1:1.65:3.4

50% Replacement

$0.98 = (191.6+\frac{399.16}{3.15} +\frac{1}{0.295} \times \frac{Fa}{3.425})\times\frac{1}{1000}$

1:1.67:3.4

52% Replacement

$0.98 = (191.6+\frac{399.16}{3.15} +\frac{1}{0.295} \times \frac{Fa}{3.43})\times\frac{1}{1000}$

1:1.68:3.4

100%Replacement

$0.98 = (191.6+\frac{399.16}{3.15} +\frac{1}{0.295} \times \frac{fa}{4.13})\times\frac{1}{1000}$

1.5:2.02:3.4

IV. EXPERIMENTAL WORK

4.1 CASTING OF SPECIMEN

A total of 20 specimens were casted considering 2 specimen for each cases with the Mix ratios derived. Table 6 shows the quantity of raw materials used as per designed.

TABLE 4: SPECIFICATIONS OF CONCRETE MIX

%		Mix ratio derived	Cement (Kg)	F.A (Kg)	C.S (Kg)	C.A (Kg)	W/C ratio
F.A	C.S						
100%	0%	1:1.32:3.4	1.5	1.98	0	5.1	0.48
62%	38%	1:1.57:3.4	1.5	1.45	0.894	5.1	0.45
60%	40%	1:1.56:3.4	1.5	1.4	0.936	5.1	0.45
58%	42%	1:1.57:3.4	1.5	1.36	0.989	5.1	0.45
56%	44%	1:1.62:3.4	1.5	1.36	1.069	5.1	0.45
54%	46%	1:1.63:3.4	1.5	1.32	1.124	5.1	0.45
52%	48%	1:1.65:3.4	1.5	1.282	1.188	5.1	0.45
50%	50%	1:1.67:3.4	1.5	1.247	1.252	5.1	0.45
48%	52%	1:1.68:3.4	1.5	1.21	1.310	5.1	0.45
0%	100%	1.5:2.02:3.4	1.5	0	3.03	5.1	0.42

Copper slag was sieved as like fine aggregate and mixed finely with the sand, so as to obtain even distribution of the grains. Fig 2 shows the finely mixed Copper slag and sand.

Fig 2 Partial replacement of Copper slag with Sand

Cube moulds of size 150x150x150 mm were used. They were cleaned thoroughly using a waste cloth and then properly oiled along its faces. Concrete was then filled in mould and then compacted using a standard tamping rod of 60 cm length having a cross sectional area of 25mm^2.

Fig 3 Casting of Cubes

From the literature review it was found that water absorption for copper slag was 0.16% compared with 1.25% for sand. This suggests that copper slag would demand less water than that required by sand in the concrete mix. Hence water cement ratio for conventional concrete i.e. (0%) was taken as per designed (0.48) and for complete replacement it was taken as 0.42 and for remaining cases it was taken as 0.45.

Therefore, it is expected that the free water content in concrete matrix will increase as the copper slag content increases which consequently will lead to increase in the workability of the concrete.

4.2 COMPRESION TESTING

The testing machine shall be equipped with two steel bearing blocks with hardened faces. One bearing block shall be spherically seated and other rigidly mounted. The testing machine shall be accurate within a tolerance of ± 1.0 to 5% of the compressive strength of the specimen.

Fig 3 Compression Test

TABLE 5: AVERAGE COMPRESSIVE STRENGTH

%	Specimen No	Weight	Load	Compressive Strength	Avg
0	A_{01}	8.132	605	26.88	**27.22**
	A_{02}	8.490	620	27.55	
38	A_{11}	8.665	620	27.55	**27.22**
	A_{12}	8.780	605	26.88	
40	A_{21}	8.980	680	30.22	**32.775**
	A_{22}	8.984	795	35.33	
42	A_{31}	8.980	670	29.75	**28.875**
	A_{32}	8.989	630	28	
44	A_{41}	9.155	615	27.33	**27.105**
	A_{42}	9.200	605	26.88	
46	A_{51}	8.845	745	33.11	**33.775**
	A_{52}	8.855	775	34.44	
48	A_{61}	9.015	695	30.889	**29.884**
	A_{62}	9.075	650	28.88	
50	A_{71}	8.910	700	31.11	**31.665**
	A_{72}	8.960	725	32.22	
52	A_{81}	9.235	660	29.33	**29.775**
	A_{82}	9.300	680	30.22	
100	A_{91}	9.215	745	33.11	**34.555**
	A_{92}	9.270	810	36	

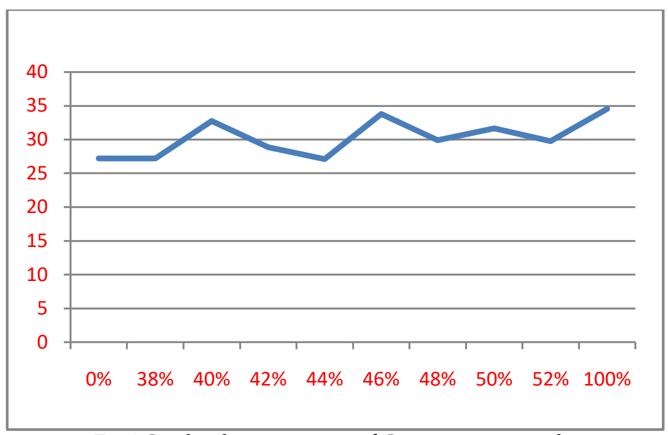

Fig 4 Graphical representation of Compressive strengths

V. RESULT AND DISCUSSION

5.1 GENERAL

The above graph shows that compressive strength of concrete at 28 days. 46% of replacement shows a considerable amount of increase in the compressive strength of concrete. And also complete replacement of copper slag also shows more improvement in strength of all. Hence this work it is evident that the replacement of copper slag with Fine aggregate from 40 to 50% Showed good improvement in strength and from that 46% showed a better improvement.

TABLE 6 % INSCREASE IN STRENGTH WITH CONVENTIONAL CONCRETE

% Replacement	Compressive strength	%Increase in strength
0% (Conventional Concrete)	27.22	
38%	27.22	0%
40%	32.775	1.189%
42%	28.875	1.06%
44%	27.105	0.995%
46%	33.775	1.2%
48%	29.884	1.1%
50%	31.665	1.16%
52%	29.775	1.093%
100%	34.555	1.26%

Though the results obtained were optimal this work was carried out for cubes which can be further studied immensely and can be updated for using in casting RC structures.

5.3 OUTCOES OF THE WORK

1. Since the % replacement we have chosen was in 2% differences, the Specimens were casted with great accuracy and care, with almost negligible wastage.
2. From this work the reduction in utilization of Fine aggregate is almost 50%
3. By replacing the fine aggregate with 50% copper slag the cost in the Fine aggregate area can be reduced up to 20%.
4. The Workability of the Concrete increases up to 12.2% on replacing Fine aggregate with Copper slag.
5. The density of concrete increases with the increase of copper slag as shown in Table 5.
6. Finally from the previous works it has been proven that replacement of Copper Slag with Fine aggregate from 40 to 50% showed Strength improvement, and from this work it is evident that from 40 to 50% replacement particularly 46% showed greater improvement in strength.
7. Since this work only focuses on the strength improvement proper admixtures can be used to increase other properties.
8. In order to meet the demand of depletion of river sand, now-a-days M sand has been prevalent in market. Copper slag can be strongly suggested and can play a vital role in replacement of Fine aggregate

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