Experimental Study on the use of Recycled Concrete Aggregate and Copper Slag in concrete

Shareen Ashraf [1], Safna Shani C.[1], Shameem P. [1], Mohamed Anees K. [2]

U.G. Student, Department of Civil Engineering, MEA Engineering College, Perinthalmanna, Kerala, India[1]

Assistant Professor, Department of Civil Engineering, MEA Engineering College, Perinthalmanna, Kerala, India[2]

ABSTRACT: The major problem world facing today is environmental pollution. Continuous industrial development causes serious problem of construction and demolition waste development, whereas on other hand there is a critical shortage of natural aggregate for the production of new concrete. Quarrying for sand and other aggregate materials can destroy and pollute mine areas. We can reduce pollution effect on environment by increasing the usage of waste concrete and industrial by-product (copper slag) in our construction industry. Construction and demolition waste includes broken concrete, bricks from buildings or broken pavement, thus recycled concrete made using such aggregate are referred to as recycled aggregate concrete. Recycled concrete aggregate are the materials for future construction. Copper slag is a by-product of copper extraction by smelting.

KEYWORDS: Recycled Aggregate Concrete (RCA), Copper Slag

I. INTRODUCTION

Aggregates which are used in concrete are obtained either from natural sources or by crushing large size rocks. In order to reduce dependence on natural aggregate in construction, artificially manufactured aggregate and some industrial waste material can be used as an alternative. Also, aggregates are considered as inert material therefore it can be easily replaced in comparison of any other constituent of concrete. Use of copper slag and recycled aggregate as aggregate in concrete reduce amount of natural aggregate in concrete and also useful in waste management.

The objective of this work is to investigate the properties of concrete with replacing fine aggregate by copper slag and coarse aggregate with RCA, and also to scrutinize the following:

1. To find the optimum proportion of copper slag that can gain maximum strength and that proportion will be used as a replacement substitute material for fine aggregate in concrete.
2. To determine the mechanical properties of concrete by replacing the coarse aggregate by crushed concrete waste or RCA.
3. To inspect the performance of concrete made with copper slag and RCA as replacement of aggregate.
4. To evaluate the compressive, tensile, flexural strength and workability of concrete by using copper slag and recycled aggregate in concrete specimens and compare it with conventional concrete.

II. RELATED WORK

An experimental investigation was conducted to study the effect of using concrete waste as a fine aggregate on the properties of cement mortars and concrete by V. Senthil Kumar et al. [1], showed that compressive strength, split tensile strength and flexural strength are in decreasing order when the percentage of recycled aggregate replacement increases.

Shahiron Shahida et al. [5], studied recycled aggregates (RA) produced from C&D waste and their use in concrete construction. The aggregate size of 10mm was taken as the optimum result because the highest figures were recorded for the split tensile test and the compressive strength test after a curing period of 28 days.

T. Ch. Madhavi [7],discussed the possibility to replace virgin fine aggregate with copper slag in structural concrete. The Results showed that replacement of copper slag can be done up to 30% exceeding it's used beyond 50% decrease the strength.

III.METHODOLOGY

The specimens were casted by using a concrete mix of M25 grade consisting of cement (PPC), fine aggregate, copper slag, coarse aggregate, recycled concrete aggregate and water. Fine Aggregate were replaced by 20%,40% and 60% with copper slag and coarse aggregate was replaced by 30% with recycled concrete aggregate (RCA).Details of the specimen casted is given in Table 1.

As per the code book IS: 10262-2009, the mix design was done for M25 grade mix and the amount of materials was calculated. Table 2 gives the quantities required for M25 grade of concrete mix.

Table 1 Details of specimens casted

SI No	Copper Slag	RCA	Cube	Cylinder	Beam
1.	0%	0%	3	3	3
2.	0%	30%	3	3	3
3.	20%	30%	3	3	3
4.	40%	30%	3	3	3
5.	60%	30%	3	3	3
Total specimens casted					45

Table 2 Mix Proportion

Grade	Cement (kg/m3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	Water	W/C ratio	Mix Proportion
25	438.13	753	1061	197.16	0.45	1:1.71:2.42

Fig 1: Casted Specimens

Fig 2: Specimens after 28 days of curing

Three cubes, cylinders and beams each were casted for each mixes. Tests on Compression strength, Split Tensile Strength and Flexural strength were conducted on the specimens after 28 days of curing. Based on the results obtained suitable mix proportion was selected for casting. Also Workability tests were conducted on fresh concrete such as Slump test and Compaction Factor Test. These results were compared with results of tests done nominal concrete mix.

IV.EXPERIMENTAL RESULTS

A. Slump Test on specimens

Slump test is the most commonly used method of measuring workability of concrete. The apparatus for conducting the slump test consists of a metallic mould in the form of a frustum of a cone. The slump value for each mix is tabulated in Table 3 and a graph is also plotted. It is observed that the slump value decreases with the addition of copper slag.

Table 3 Slump Values

Copper Slag	RCA	Slump Value (mm)
0 %	0 %	30
0 %	30 %	26
20 %	30 %	24
40 %	30 %	22
60 %	30 %	21

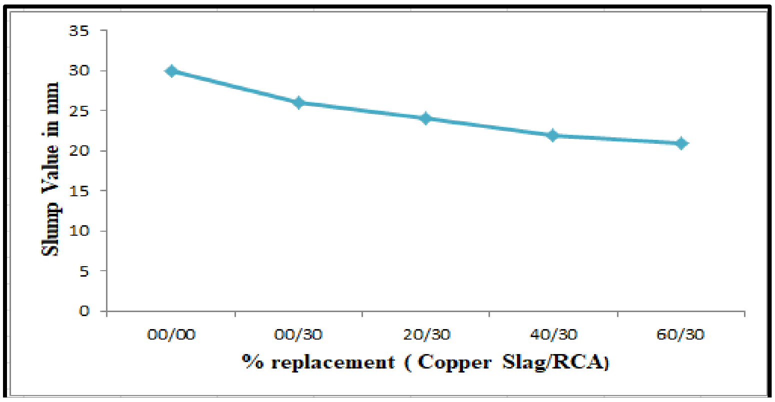

Fig 3: Variation in Slump

B. Compaction Factor Test on specimens

The compaction factor value for each mix is tabulated in Table 4 and a graph is also plotted. It is observed that the compaction factor value decreases with the addition of copper slag.

Compaction Factor = $\frac{Weight\ of\ Partially\ compacted\ concrete}{Weight\ of\ fully\ compacted\ concrete}$

Table 4 Compaction Factor Values

Copper Slag	RCA	Compaction Factor
0 %	0 %	0.82
0 %	30 %	0.81
20 %	30 %	0.8
40 %	30 %	0.8
60 %	30 %	0.81

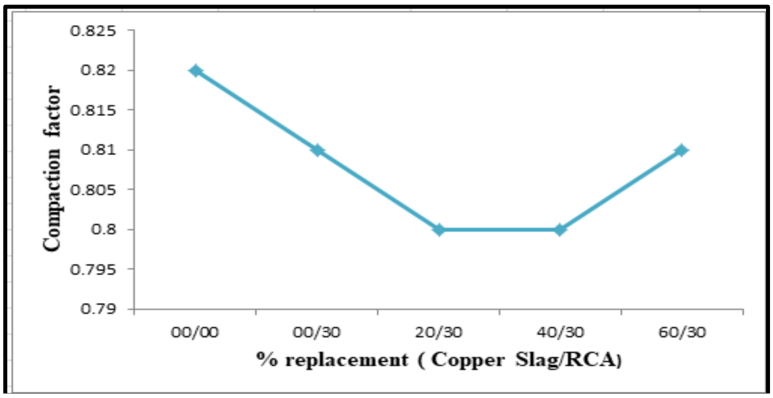

Fig 4: Variation in Compaction Factor

The workability is found to be in decreasing order. It may be due to the absorption of water by the recycled concrete aggregate. From the workability results, it is confirmed that, the addition of Copper Slag also decreases the workability of concrete.

C. Compression Test on Cube Specimens

The compressive strength of cubes were tested at 28 days. The compressive strength of cube at 28 days with 20%, 40%, and 60% replacement of fine aggregate with copper slag and 30 % replacement of coarse aggregate with RCA is shown in Table 5.

Fig 5: Compression test on cube specimen

Table 5 Compressive Strength of concrete at 28 days

Copper Slag (%)	RCA (%)	Compressive Strength (N/mm^2)	% Increase in Strength
0	0	37.61	0
0	30	38.59	2.6
20	30	40.56	7.8
40	30	37.006	1.6
60	30	34.88	7.2

The results in Table 5 show the compressive strength of concrete with varying Copper slag and RCA at 28 days. The percentage change in strength with respect to normal concrete at 28 days is graphically plotted. Fig. 5 shows the testing of sample. Compressive strength of mix 00:00 obtained at 28 days is 37.61 N/mm^2, 00:30 mix i.e. partial replacement of coarse aggregate with RCA (30%) is 38.59 N/mm^2. Compressive strength of 20:30 mix with partial replacement of Fine aggregate with copper slag (20%) at 28 days is 40.56 N/mm^2, 40:30 mix with 40% replacement of FA with copper slag is 37.006 N/mm^2, and 60:30 mix with 60% replacement with copper slag is 34.88 N/mm^2. Also the % increase in strength is calculated.

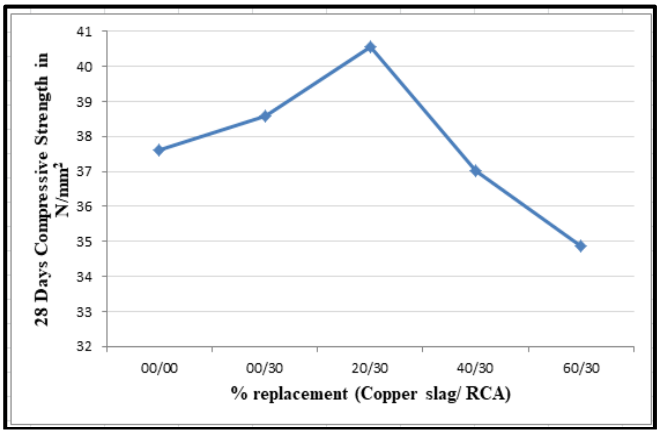

Fig 6: Variation in Compression strength

The compressive strength of concrete, in which the coarse aggregate is partially replaced with RCA, increases. Along with the addition of copper slag with RCA the strength increases up to 20% replacement of copper slag as fine aggregate and then follows a downward trend with subsequent addition.

D. Split Tensile Test on cylindrical specimen

The tensile strength of concrete is determined by splitting the cylinder across the vertical diameter. Split tensile strength is an indirect method of finding out the tensile strength of concrete. The test was carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine. The load was applied until the specimen fails.
The split tensile strength is calculated using the formula, $F = 2P / \Pi dL$
Where,
P=applied load, d=diameter of the specimen, L=length of the specimen

Fig 7: Split tensile test on cylindrical specimen

Table 6 Split tensile strength of concrete at 28 days

Copper Slag (%)	RCA (%)	Split Tensile Strength (N/mm^2)	% Increase in Strength
0	0	3.06	0
0	30	3.17	3.59
20	30	3.98	30.06
40	30	3.69	20.5
60	30	3.46	13.07

The results in Table 6 show the split tensile strength of concrete with varying percentage of copper slag and RCA at 28 days Along with split tensile strength, the percentage change in split tensile strength with respect to normal concrete is plotted. Fig. 7 shows the testing of Sample for Split Tensile Strength. Split Tensile strength of mix 00:00 obtained at 28 days is 3.06 N/mm^2, 00:30 mix i.e. partial replacement of coarse aggregate with RCA (30%) is 3.17 N/mm^2. Compressive strength of 20:30 mix with partial replacement of Fine aggregate with copper slag (20%) at 28 days is 3.98 N/mm^2, 40:30 mix with 40% replacement of FA with copper slag is 3.69 N/mm^2, and 60:30 mix with 60% replacement with copper slag is 3.46 N/mm^2. Also the % increase in strength is calculated.

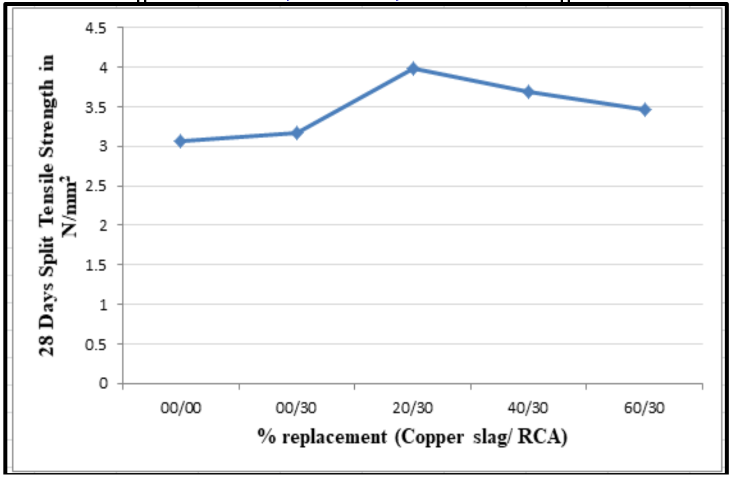

Fig 8: Variation in split tensile strength

The split tensile strength of concrete in which the coarse aggregate is partially replaced with RCA (30%) and fine aggregate is partially replaced with copper slag increases first up to 20% addition of copper slag and then decreases with subsequent addition.

D. Flexural Strength test on beam specimen

The standard size of the specimens 50 x 10 x 10 cm is used. The mould should be made of metal or cast iron, with sufficient plate thickness to prevent spreading or warping. The testing machine may be of sufficient capacity for the testing and rate of loading as specified. The load is applied through the roller (third-point load).The flexural strength of specimen is expressed as modulus of rupture, f_b.

$$\text{Flexural strength, } f_b = 1.5PL / bd^2$$

Where P = Applied load, L = Length of specimen ,b, d = Cross section dimensions of specimen.

Fig 9: Flexural strength test on beam specimen

Table 7 Flexural strength of concrete at 28 days

Copper Slag (%)	RCA (%)	Flexural Strength (N/mm^2)	% Increase in Strength
0	0	6.53	0
0	30	7.85	20.2
20	30	8.86	34.9
40	30	6.97	6.7
60	30	6.45	1.22

The results in Table 7 show the Flexural strength of concrete with varying percentage of copper slag and RCA at 28 days. Along with Flexural strength, the percentage change in Flexural strength with respect to normal concrete is plotted. Fig. 9 shows the testing of flexural strength. Flexural strength of mix 00:00 obtained at 28 days is 6.53 N/mm^2, 00:30 mix i.e. partial replacement of coarse aggregate with RCA (30%) is 7.85 N/mm^2. Compressive strength of 20:30 mix with partial replacement of Fine aggregate with copper slag (20%) at 28 days is 8.86 N/mm^2, 40:30 mix with 40% replacement of FA with copper slag is 6.97 N/mm^2, and 60:30 mix with 60% replacement with copper slag is 6.45 N/mm^2. Also the % increase in strength is calculated.

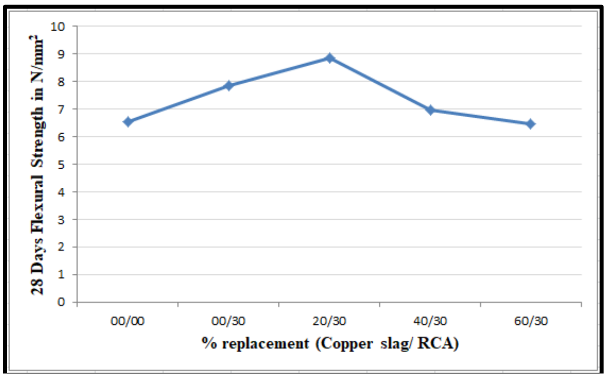

Fig 10: Variation in flexural strength

The flexural strength of concrete in which the coarse aggregate and fine aggregate is replaced with RCA and copper slag respectively increases first and subsequent addition of copper slag decreases the strength.

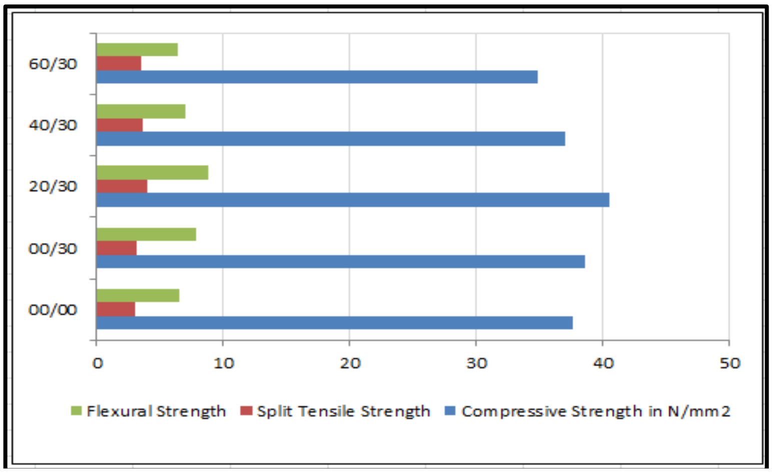

Fig 11: Combine graph of waste replacement

V. CONCLUSION

Copper slag and RCA can be used as a suitable material for replacement of aggregate in concrete. RCA along with Copper slag in concrete showed a considerable increase in strength when used with in permissible quantities. Copper slag can be used up to 20% but when used beyond 40% along with RCA results in decrease in strengths. The maximum strength was achieved for 20 % replacement of fine aggregate with copper slag and 30% replacement of coarse aggregate with RCA. Further addition of copper slag reduces the strength. Compressive Strength was increased by 7.8% when compared to Nominal mix for 20% replacement of fine aggregate with Copper Slag and 30% replacement of coarse aggregate with RCA. Split tensile Strength was increased by 30.06% when compared to Nominal mix for 20% replacement of fine aggregate with Copper Slag and 30% replacement of coarse aggregate with RCA. Flexural Strength was increased by 34.9% when compared to Nominal mix for 20% replacement of fine aggregate with Copper Slag and 30% replacement of coarse aggregate with RCA. It is to be concluded that the compressive strength, split tensile strength and flexural strength are in the decreasing order when the percentage of copper slag considerably increases. Therefore it is advisable to replace fine aggregate by copper slag at limited extent. The workability was found to be in a decreasing order. This may be due to the absorption of water by RCA. However, the concrete still has a strength that would make it suitable for minor construction and structural works. Use of recycled aggregates in concrete provides a promising solution to the problem of construction and demolition waste management. Copper Slag and RCA has a potential to provide as an alternative to aggregate up to an extent and helps in maintaining the environmental as well as economical balance. Also copper slag contributes to natural sand conservation and by using copper slag as fine aggregate as we can make environment more sustainable. In conclusion, usage of RCA and copper slag in concrete production may help solve a vital environmental issue apart from being a solution to the problem of inadequate concrete aggregates in concrete.

REFERENCES

[1] V. Senthil Kumar, P. Jayyabharath, G. Kesavan,V. Karthikeyan , *Experimental Study on replacing aggregates by concrete waste* Volume 5, Issue 5, May 2018, pp. 1057 – 1073.

[2] J. Vijayaraghavan, A. Belin Jude, J. Thivya, *Effect of copper slag, iron slag and recycled concrete aggregate on the mechanical properties of concrete*, Volume 53, September 2017, pp. 219 – 225.

[3] Abhinav Shyam , Abdullah Anwar , Syed Aqeel Ahmad, *Experimental Study on the Behavior of Copper Slag as Partial Replacement of Fine Aggregate in Concrete,* Volume 5 Issue 4 , April 2017 , pp. 1465 – 1474.

[4] Ashwin Raval , B M Purohit , A R Darji, *Experimental Investigation on Use of Copper Slag and Recycled Aggregate as a Fine Aggregate in Concrete,* Volume 5 Issue 2, February 2017, pp. 649 – 653.

[5] Shahiron Shahidana, Mohamad Azim Mohammad Azmib, Kumanan Kupusamy, Sharifah Salwa Mohd Zukid , Noorwirdawati Ali, *Utilizing Construction and Demolition (C&D) Waste as Recycled Aggregates (RA) in Concrete,* 2016, pp. 1028 – 1035.

[6] Ishimaru K., Mizuguchi H. , Hashimoto C., Ueda T., Fujita K., Ohmi M ,*Properties of copper slag and second class fly ash as a part of fine aggregate,* 2015 , pp. 828 – 833.

[7] T. Ch. Madhavi , *Copper Slag In Concrete As Replacement*, 2014.

[8] Akira Shintani, Kazuhisa Yoda, *Building application of recycled aggregate concrete for upper-ground structural elements*, 2014, Volume 67, pp.307- 430.

[9] R R Chavan , D B Kulkarni, *Performance of Copper Slag on Strength Properties as Partial Replacement of Fine Aggregate in Concrete Mix Design,* 2013, Volume 4, pp.95-98, International Journal of Advanced Engineering Research and Studies.

[10] Obinna Onuaguluchi, Ozgur Eren, *Cement Mixtures Containing Copper Tailings as an Additive: Durability Properties*, 2012, Volume 6, pp.1029-1036, Materials Research.

[11] Ashraf M. Wagih, Hossam Z. EI-Karmoty, Magda Ebid, Samir H. Okba, *Recycled construction and demolition concrete waste as aggregate for structural concrete*, 2012, Volume 9, pp.193-200, Housing and Building NRC.