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An Experimental Study of Partial Replacement of Recycled Coarse Aggregate and Copper Slag in Concrete

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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. Two ton copper slag is formed while producing one ton of copper. Aim of this study is to use demolished concrete waste and copper slag in the production of new concrete and to reduce environmental pollution. Concrete mix consist of cement, fine aggregate, recycled aggregate concrete, copper slag and water. Mix design is to be determined using IS code method. Concrete is to be prepared by replacing coarse aggregate by recycled concrete aggregate and partially replacing fine aggregate by copper slag. Compressive strength, split tensile strength, flexural strength and workability is to be determined and compared with that of conventional concrete.

Keywords—Recycled coarse aggregate, Copper slag, Industrial by-product.

I. INTRODUCTION

Concrete is a widely used construction material for various types of structures due to its durability. For a long time it was considered to be very durable material requiring a little or no maintenance. Many environmental phenomena are known significantly for the durability of reinforced concrete structures. We build concrete structures in highly polluted urban and industrial areas, aggressive marine environments and many other hostile conditions where other materials of construction are found to be non-durable. Utilization of industrial soil waste or secondary materials has been encouraged in construction field for the production of cement and concrete because it contributes to reducing the consumption of natural resources. The best solution would be to reuse the demolished concrete. Presently, demolished concrete is being used as a base material in highway construction. As a further scope towards the use of waste concrete or Recycles Concrete Aggregate, the concrete rubble is also being used as a substitute for natural aggregate in making new concrete.

In India, by-products and waste materials are being generated by various types of industries. Disposal of waste materials effects the environment in various zones. Therefore, these waste materials can be recycled and it is great potential in construction industry. Many researchers found that concrete made with wastes and by-products like fly ash, silica fume, copper slag etc acquires excellent properties than the conventional concrete in terms of strength, performance and durability. Hence, in this project, copper slag is taken to investigate its suitability as a replacement material for fine aggregate while making concrete. Copper slag is an industrial by-product material produced during the smelting and refining process of copper, which can be used for a surprising number of applications in the construction field. It is also having similar physical properties of sand, considered as an alternative material to the river sand. It is the waste product material of copper. Disposal of this waste causes environmental pollution. The construction field is the only area where the safe use of waste material like copper slag is possible. When it is taken as a replacement material in concrete, it lessens the environmental pollution, space problem and also lessens the cost of concrete.

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:

- 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
- To determine the mechanical properties of concrete by replacing the coarse aggregate by crushed concrete waste or RCA
- To inspect the performance of concrete made with copper slag and RCA as replacement of aggregate.

- 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. REVIEW OF LITERATURES

Abhinav Shyam et al. (2017), An experimental investigation was carried out for M-40 grade of concrete mixes with partial replacement of Fine Aggregate (Sand) by Copper Slag in proportions of 0%, 10%, 20%, 30%, 40% and 50%. Compressive Strength, Split Tensile Strength and

Flexural Strength at the ages of 28 days for various combinations of Copper Slag and Sand were investigated. The maximum strength was achieved for 40 % replacement of fine aggregate with copper slag. Further addition of copper slag reduces the strength. Copper Slag has a potential to provide as an alternative to fine aggregate up to 40% and helpsin maintaining the environmental as well as economical balance.

D. Priyadharshini et al. (2018),This paper focuses on using M40 grade of concrete for partial and full replacement of sand with copper slag and recycled coarse aggregate. The concrete with copper slag and RCA shows better workability. It was concluded that compression strength was increased with the addition of copper slag in concrete up to 60% and then it was found to be decreased. For the full replacement of sand with copper slag, the strength was increased to 40.75 N/mm2.The split tensile strength was increased with the addition of copper slag in concrete similar to compressive strength.

Ishimaru et al. (2015) , In this study, the fundamental properties of concrete using copper slag or second class fly ash as a part of fine aggregate to apply for plain concrete structure is investigated. It is concluded that the concrete of 20mm in coarse aggregate maximum size, 50% in water- cement ratio and 40mm in coarse aggregate maximum size, 60% in water- cement ratio and up to 30%, except in the case of 50% in water-cement ratio of fly ash concrete is possible to 20%, at in volume percentage of sand using copper slag or secondclass fly ash is applicable for concrete structure. Up to 20% (in volume) of copper slag or class II fly ash as fine aggregates substitution can be used in the production of concrete.

R R Chavan et al. (2012), reported on an experimental program to investigate the effect of using copper slag as a replacement of fine aggregate on the strength properties. Copper slag isthe waste material of matte smelting and refining of copper such that each ton of copper generates approximately 2.5 tons of copper slag. Copper slag is one of the materials that is considered as a waste which could have a promising future in construction Industry as partial or full substitute of aggregates. In this research work, M25 grade concrete was used and tests were conducted for various proportions of copper slag replacement with sand of 0 to 100% in concrete. The obtained results were compared with those of control concrete made with ordinary Portland cement and sand.

Shahiron Shahida et al. (2016), This study discusses recycled aggregates (RA) produced from C&D waste and their use in concrete construction. Along with a brief overview of the engineering properties of recycled aggregates, the study also gives a summary of the effect of recycled aggregates on the properties of fresh and hardened concrete. This study found that the optimum results for the split tensile test, compressive strength test and water absorption test were obtained for the aggregates measuring 10mm. 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.

V. Senthil Kumar et al. (2018) , 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 them. Various mortar and concrete mixtures were prepared with different proportions of concrete waste ranging from 0% (for the control mixture) to 100% as aggregate replacement. Cement mortar mixtures were evaluated for compressive strength, whereas concrete mixtures were evaluated for workability, density, compressive strength, tensile strength, flexural strength and durability. The results obtained for concrete indicated that Compressive strength, split tensile strength and flexural strength are in decreasing order when the percentage of recycled aggregate replacement increases.

III. EXPERIMENTAL INVESTIGATION

Initially, basic tests were conducted for fine aggregate, coarse aggregate and cement to check their suitability for concrete making.

A. Experimental Investigation

The Apparatus consist of moulds, mixer, trowel and tamping rod (steel bar 16 mm diameter and 60 cm long). Thorough mixing of materials is essential for the production of uniform concrete. As the mixing cannot be thorough, it is desirable to add 15% more materials. By laboratory batch mixer, first mix the Coarse aggregate, RCA, fine aggregate and copper slag until the mixture is thoroughly blended. Then, add the cement and water and mix. Finally, add the remaining water and mix until the concrete appears to be homogeneous and of the required consistency. The homogeneous concrete mix is discharged on a dry platform.

On the course of time, the moulds are cleaned and applied with thin film of oil. The fresh concrete is filled inthe mould in three layers of 5 cm depth. Each layer is compacted with tamping rod uniformly with 25 blows. The purpose of compaction is to avoid entrapped air inside the concrete moulds. After the top layer has been compacted, level top surface with a trowel. During pouring of concrete, it is better to avoid wasting of concrete for effective and economical usage. The specimens are demoulded after 24 hours from the process of moulding. If the concrete has not achieved sufficient strength to enable demoulding the specimens, then the process must be delayed for another 24 hours care should be taken not to damage the specimen during the process because, if any damage is caused, the strength of the concrete may get reduced.

TABLE I. SPECIMEN CASTED

S.I. No.	Copper Slag	RCA	Cylinder	Beam	Cube
1	0%	30%	6	6	6
2	0%	30%	6	6	6
3	20%	30%	6	6	6
4	40%	30%	6	6	6
5	60%	30%	6	6	6
Total specimens casted					90

After demoulding, specimen is marked with a legible identification, on any of the faces. The concrete specimens are placed in a curing tank after demoulding for 28 days of curing periodFor obtaining flexure behavior of RC beams, beam of size 100×200×1500mm were casted in wooden moulds to maintain the dimension of the beam in the laboratory. The bottom flexural reinforcement consisted of two numbers of 12mm diameter bars providing a total cross section of 226.19mm2 and the top.

FIG I. SPECIMEN CASTED

FIG II. SPECIMEN AFTER 28 DAYS OF CURING

B. Test Setup

TABLE II. MIX POPORTION

Grade	**Cement (kg/m^3)**	**F.A (kg/m^3)**	**C.A (kg/m^3)**	**Water (l/m^3)**	**W/C**	**Mix Proportion**
25	438.13	753	1061	197.16	0.45	1:1.71:2.42

- Compressive Strength of Concrete cube Specimens is tested after 7thand 28th days. The test is done using Compression Testing Machine. As per IS456:2000 and IS516:1959 the compressive strength value of cube specimen should not less than 30 N/mm2.
- Split Tensile Strength of Concrete Cylinder Specimens is tested after 28th days. The test is done using Compression Testing Machine.
- As per IS 456:2000 and IS5816:1999 the split tensile strength of concrete should not less than 1/10 of fck.

C. Result

TABLE III. COMPRESSIVE STRENGTH TEST RESULT

MIX (Copper Slag/ RCA) %	**Specimen**	**Compressive Strength (N/mm^2)7 days**	**Mean (N/m m^2)**	**Compressive Strength (N/mm^2)28 days**	**Mean (N/mm^2)**
00/00	1	16.30	16.50	38.22	37.61
	2	16.22		36.41	
	3	17.006		38.22	
00/30	1	17.42	17.32	39.11	38.59
	2	17.22		38.22	
	3	17.32		38.44	
20/30	1	18.80	18.58	40.8	40.56
	2	18.44		40.44	
	3	18.50		40.44	
40/30	1	16.42	15.69	36.44	37.006
	2	15.22		37.77	
	3	15.45		36.81	
60/30	1	15.11	14.57	35.11	34.88
	2	14.06		34.66	
	3	14.55		34.88	

TABLE IV. SPLIT TENSILE STRENGTH TEST RESULT

MIX (Copper Slag/ RCA) %	**Specimen**	**Compressive Strength (N/mm^2)7 days**	**Mean (N/m m^2)**	**Compressive Strength (N/mm^2)28 days**	**Mean (N/mm^2)**
00/00	1	2.20	2.28	3.25	3.06
	2	2.56		3.11	
	3	2.10		2.82	
00/30	1	2.81	2.90	3.39	3.17
	2	3.001		2.82	
	3	2.91		3.32	
20/30	1	3.01	3.47	3.96	3.96
	2	3.60		4.1	
	3	3.81		3.89	
40/30	1	2.15	2.05	3.53	3.69
	2	1.91		3.81	
	3	2.11		3.74	
60/30	1	1.81	1.79	3.53	3.46
	2	2.01		3.46	
	3	1.55		3.39	

TABLE V.FLEXURAL STRENGTH TEST RESULT

MIX (Copper Slag/ RCA) %	Specimen	Flexural Strength (N/mm^2) 7 days	Mean (N/mm^2)	Flexural Strength (N/mm^2) 28 days	Mean (N/mm^2)
00/00	1	3.50	3.37	6.61	6.53
	2	3.41		6.56	
	3	3.22		6.45	
00/30	1	3.81	3.57	7.95	7.85
	2	3.25		7.65	
	3	3.66		7.95	
20/30	1	4.22	4.10	8.62	8.86
	2	3.91		9.15	
	3	4.31		8.81	
40/30	1	3.15	3.52	6.6	6.97
	2	3.87		7.2	
	3	3.56		7.12	
60/30	1	2.98	3.19	6.3	6.45
	2	3.10		6.9	
	3	3.51		6.15	

D. Discussion

TABLE VI. COMPRESSIVE STRENGTH

Copper Slag (%)	RCA (%)	Compressive Strength (N/mm^2) 7-days	Compressi ve Strength (N/mm^2) 28-days	% Increase or Decrease in Strength 7-days	% Increase or Decrease in Strength 28-days
0	0	16.50	37.61	0	0
0	30	17.32	38.59	4.9	2.6
20	30	18.58	40.56	12.6	7.8
40	30	15.69	37.006	4.9	1.6
60	30	14.57	34.88	11.69	7.2

TABLE VII. SPLIT TENSILE STRENGTH

CopperSlag (%)	RCA(%)	Split TensileStrength (N/mm^2) 7-days	Split TensileStrength (N/mm^2) 28-days	% Increaseor Decrease in Strength7-days	% Increaseor Decrease in Strength28-days
0	0	2.28	3.06	0	0
0	30	2.90	3.17	27.19	3.59
20	30	3.47	3.98	52.19	30.06
40	30	2.05	3.69	10.08	20.5
60	30	1.79	3.46	21.49	13.07

TABLE VIII. FLEXURAL STRENGTH

Copper Slag (%)	RCA (%)	Flexural Strength (N/mm^2) 7-days	Flexural Strength (N/mm^2) 28-days	% Increase or Decrease in Strength 7-days	% Increase or Decrease in Strength 28-days
0	0	3.37	6.53	0	0
0	30	3.57	7.85	5.9	20.2
20	30	4.10	8.86	21.66	34.9
40	30	3.52	6.97	4.45	6.7
60	30	3.19	6.45	5.34	1.22

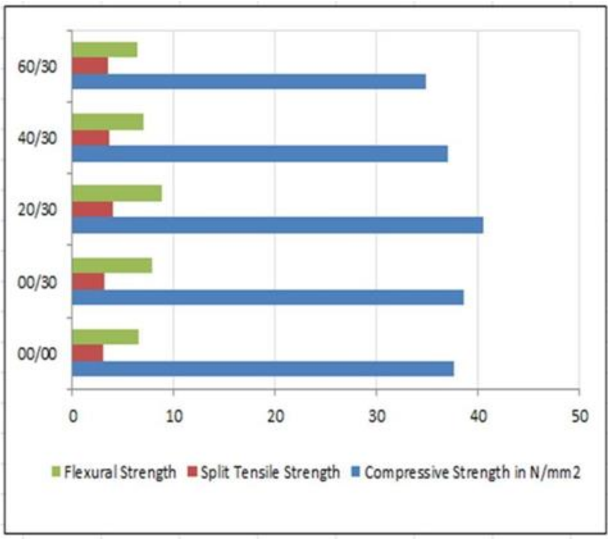

FIG III. COMBINED GRAPH OF WASTE REPLACEMENT

IV. 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 thatwould 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.

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