

# **Utilization of Solid Waste Particles as Aggregates in Concrete**

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**ABSTRACT:** The river sand is one of the unavoidable ingredients in Civil Construction. The Construction activities are increasing day by day. This usage of river sand is increasing its scarcity and its price in all parts of the country. Reducing the consumption of river sand in construction is a major issue while considering the Economic view. It also helps to save the environment by reducing the harmful impact of sand mining. The Discarded vehicle tyres which are historically been disposed of into landfills constitute an important part of the solid waste. Tyre disposal to landfills is problematic, as waste rubber is not easily biodegradable. An emerging field for the reuse of scrap tyres is in the production of concrete, where rubber tyres can be used as a partial replacement to natural aggregates. This has the additional advantage of saving in natural resources. In this study, an attempt has been made to control the environmental pollution and to save the natural resources by using the discarded rubber tyres for partial replacement for coarse aggregates and Copper slag for the partial replacement for fine aggregates.

**KEYWORDS:** Copper Slag; discarded rubber tyres; compression test; rebound hammer test; split tensile test

## **I. INTRODUCTION**

Due to the rapid growth in population, the numbers of vehicles are increasing every day. The rubber tyres used in vehicles are thrown away after it is undergone to wear and tear. It is causing lot of environmental pollution. Discarded vehicle tyres constitute one important part of solid waste which has historically been disposed of into landfills. It is estimated that in India about 400 million tyres per year (i.e. more than 1,00,00,00 tyres per day) have been ending up as waste. This number is expected to increase by a further 63% by 2021, due to the forecasted growth in road traffic. This has become a major solid waste disposal problem. Tyre disposal to landfills is problematic, as waste rubber is not easily biodegradable. Stockpiled tyres also present many, health, environmental and economic risks through air, water and soil pollution, littering the landscape, and providing a breeding habitat for various pests. Moreover, tyres cause serious fire hazards: once set alight, they burn fiercely, producing a number of chemicals that are harmful to the environment. An emerging field for the reuse of scrap tyres is in the production of concrete, where tyre rubber can be used as a partial replacement to natural aggregates. This has the additional advantage of saving in natural resources. Shredded or ground tyres are different to other waste materials with a potential for re-use, because their production method is now well developed. Hence, the reuse of this material in concrete could have both environmental advantages and at the same time ensure economic viability.

The Civil Engineering Construction works are increasing day by day because of the rapid growth of the urbanization. In Civil Construction, river sand is one of the unavoidable ingredients. Due to the high demand and scarcity of river sand, the price hike is beyond the limits in all parts of the country. Excavation of more and more sand from the river bed, adversely affects the environment to a large extent. It is very much important to reduce the consumption of river sand in construction works. In this regard, an attempt to reduce the usage of river sand by partial substitution of river sand with copper slag is being done. 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. Since it has a higher composition of  $Fe_2O_3$  the density of copper slag is relatively higher when compared to other materials. Sterlite

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industries (India) Ltd, Tuticorin, India produces 4 lakh tons of copper per year. For every ton of copper production, about 2.2 tons of copper slag is generated. Therefore, in India 8 lakh tons of copper slag is generated every year. It was obtained as a result of manufacturing of copper electrodes in Sterlite industry. Copper slag have been widely used for abrasive tools, roofing granules, cutting tools, abrasive, tiles, glass, road base construction, rail road ballast and cement and concrete industries. Several researchers have investigated the possible use of copper slag as fine and coarse aggregates in normal concrete and its effect on different mechanical properties of mortar and concrete.

## II. EXPERIMENTAL PROGRAM

### A. Materials required

1) *Cement*: Ordinary Portland Cement of grade 53 is used for the experiments [1-2]. The specific gravity of cement is 3.15.

2) *Coarse and Fine Aggregates*: Coarse aggregates are purchased from a nearby crusher in Chennai. Coarse aggregate with the size of 20mm were used. The fine aggregate was river sand which has the specific gravity of 2.55 and bulk density of 1.61

3) *Copper slag*: Copper slag is a by-product obtained during the production of copper in copper industries. Copper slag used in this work was brought from Sterlite industries (India) Ltd, Tuticorin.

4) *Discarded rubber tyres*: Rubber Tyres are obtained from a near work shop and is cut into pieces of 20 mm size. It is used to replace the coarse aggregates in some percentages [3-4].

## III. LABORATORY TESTING MACHINE

### A. Physical properties of Copper Slag

TABLE I. PHYSICAL PROPERTIES OF COPPER SLAG

Physical Properties	Sand	Copper Slag
Particle Shape	Irregular	Irregular
Type	River Sand	Air Cooled
Appearance	Brownish yellow	Black and glassy
Specific Gravity	2.57	3.91
Percentage of voids %	33	43
Water Absorption %	1.25	0.15-0.20
Moisture Content %	0.5	0.1
Angle of internal friction	45°	53°20'
Bulk Density g/cc	1.71	2.08

### B. Mix Design and Sample Preparation

The mix design chosen for this study is 1: 1.38: 3.23 with water/cement ratio as 0.50. Concrete mixes of different proportions of copper slag and discarded rubber tyres are being used [5-7]. 0-50% replacement of sand with copper slag and 0-20% replacement of coarse aggregates with discarded rubber tyre pieces of 20 mm size. One set of cubes, cylinders and beams are prepared with 40% replacement with copper slag and 15% replacement with discarded rubber tyre pieces. Total 11 samples were prepared. The slump tests were done on fresh concrete to determine its workability. The specimens were demoulded after 24 hours, cured in water and then tested at room temperature [8].

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TABLE II. CONCRETE MIXES WITH DIFFERENT PROPORTIONS OF CEMENT(C), COPPER SLAG(S) AND DISCARDED RUBBER TYRES (RT). ALL VALUES IN KG/CU.M

Material	C	S	W	F.A	C.A	RT
S 0	14.06	0	7L	19.4	45.37	0
S 10	14.06	1.93	7L	17.4	45.37	0
S 20	14.06	3.88	7L	15.5	45.37	0
S 30	14.06	5.8	7L	13.6	45.37	0
S 40	14.06	7.75	7L	11.6	45.37	0
RT 5	14.06	9.69	7L	9.69	43.1	2.3
RT 10	14.06	0	7L	19.4	40.83	4.5
RT 15	14.06	0	7L	19.4	38.56	6.8
RT 20	14.06	0	7L	19.4	36.3	9.1
S 40 RT 15	14.06	7.75	7L	11.6	38.56	6.8

[S10 means Copper slag 10% replaced, RT5 means Rubber Tyres 5% Replaced]

## IV. RESULTS

### A. Compressive Strength of Cubes

To determine the compressive strength, cube moulds of size 150x150x150 mm were used. 33 cubes were casted with different proportions of copper slag and rubber pieces. The moulds were cleaned thoroughly using a waste cloth and then properly oiled along its faces [9], [14]. Concrete was then filled in mould and then compacted using a standard tamping rod of 60 cm length having a cross sectional area of 225mm<sup>2</sup>. The table below shows the test results obtained on the compressive strength test on cubes.

TABLE III. COMPRESSIVE STRENGTH OF CUBE SPECIMENS AFTER 28 DAYS

S.No	Material	Load K.N	Avg Load	Compr. Strength N/mm <sup>2</sup>	% Increase In Strength
1	S 0	800 820 830	816.7	36.30	0
2	S 10	900 890 920	903.3	40.14	13.7%
3	S 20	980 960 980	973.3	43.26	22.5%
4	S 30	990 1030 1010	1010	44.9	27.2%
5	S 40	1100 1090 1050	1080	48	35.9%
6	S 50	900 910 910	906.7	40.29	14.10%
7	RT 5	810 840 830	826.7	36.74	4%
8	RT 10	850 820 820	830	36.88	4.5%
9	RT 15	820 830 800	816.7	36.3	3%
10	RT 20	780 800	786.7	34.9	-1.16%

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		780			
11	S 40 RT 15	950 940 960	950	42.22	19.5%

### B. Split tensile test on Cylinders

To determine the split tensile strength, cylinder moulds of diameter 150mm and length 300mm were casted. Totally, 33 cylindrical specimens were casted with different proportions of copper slag. The crude oil was applied along the inner surfaces of the mould for the easy removal of casted cylinder from the mould [10-11].

Split tensile strength =  $\frac{2P}{\pi l d}$ , P= Ultimate Load at failure, L=Length of specimen, D=Diameter of cylindrical specimen

TABLE IV. SPLIT TENSILE TEST ON CYLINDER SPECIMEN AFTER 28 DAYS

S.No	Material	Ultimate Load KN	Avg Load	Tensile Strength N/mm <sup>2</sup>	% Increase In Strength
1	S 0	230 220 240	230	3.25	0
2	S 10	240 260 270	256.7	3.63	11.7
3	S 20	250 260 280	263.3	3.73	14.8
4	S 30	300 290 290	293.3	4.15	27.7
5	S 40	300 330 320	316.7	4.48	37.8
6	S 50	280 280 260	273.3	3.87	19%
7	RT 5	230 230 250	236.7	3.35	3%
8	RT 10	240 240 250	243.3	3.44	5.8%
9	RT 15	250 260 250	253.3	3.58	10%
10	RT 20	220 210 200	210	2.97	-5.7%
11	S 40 RT 15	280 260 280	273.3	3.87	19.1%

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### C. Flexural strength of Beams

Beam specimens of size 1000 x150 x150mm are casted. To conduct the test the beam specimens were placed on the loading frame. Plumb bop was used to correct the centre of the beam [12]. Two distance pieces were kept at the one third distances from both the ends. Loading frame was placed upon the distance pieces and its centre was corrected using plumb bob. Two point loading system was adopted for the test [15].

Modulus of rupture=  $PL / BD^2$ , P = ultimate load in KN, L = length of beam in m, B = Average width of specimen in m, D = Average depth of specimen in m.

TABLE V. FLEXURAL STRENGTH TEST ON BEAM SPECIMEN AFTER 28 DAYS

S.No	Material	Ultimate Load Tonnes	Avg Load	Flexural Strength N/mm <sup>2</sup>	% Increase In Strength
1	S 0	12.45 12.35 12.10	12.3	36.44	0
2	S 10	13.5 13.6 13.2	13.4	39.70	8.9%
3	S 20	14.8 14.75 14.5	14.7	43.55	18.5%
4	S 30	16.10 15.8 16.15	16.01	47.43	30.16
5	S 40	16.68 17.05 17.30	17.01	50.40	38.3%
6	S 50	15.50 15.7 15.3	15.5	45.92	26%
7	RT 5	12.30 12..20 12.50	12.33	36.53	0.24%
8	RT 10	13.4 13.2 13.45	13.35	39.55	8.53%
9	RT 15	12.9 13.2 13.4	13.12	38.87	6.68%
10	RT 20	12.0 12.2 12.0	12.0	35.55	-2.44%
11	S 40 RT 15	14.4 14.8 14.0	14.73	43.64	19.76%

### D. Water absorption test

It was observed that the water absorption of copper slag admixture concrete is lesser than normal concrete. When copper slag is replaced by 40%, the water absorption is very less [13].

TABLE VI. WATER ABSORPTION TEST ON CUBE SPECIMEN AFTER 60 DAYS

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S.No	Material	Wt of Saturated Specimen kg	Wt of Oven dried Specimen kg	% Increase
1	S 0	8.30	8.0	3.7%
2	S 10	8.56	8.25	3.75%
3	S 20	9.0	8.78	2.5%
4	S 30	8.8	8.50	3.5%
5	S 40	9.30	9.00	3.4%
6	S 50	9.1	8.85	2.83
7	RT 5	8.3	7.95	4.4
8	RT 10	8.2	7.8	5.1
9	RT 15	8.0	7.60	5.3
10	RT 20	8.15	7.68	6.12
11	S40, RT15	8.80	8.45	4.4

### E. Ultrasonic Pulse wave velocity test

The Ultrasonic pulse velocity of concrete depends on the materials and the mix proportion used in making concrete and it is related to its density and modulus of elasticity.

TABLE VII. RESULTS FOR ULTRASONIC PULSE VELOCITY TEST

S.No	Material	Avge Transit Time $\mu$ sec	Distance mm	Avge Pulse Vel. Km/s	Concrete Quality
1	S 0	33.5	150	4.47	Excellent
2	S 10	32.2	150	4.65	Excellent
3	S 20	31.8	150	4.71	Excellent
4	S 30	31.5	150	4.76	Excellent
5	S 40	30.3	150	4.95	Excellent
6	S 50	31.8	150	4.71	Excellent
7	RT 5	33.6	150	4.46	Excellent
8	RT 10	33.4	150	4.49	Excellent
9	RT 15	34.0	150	4.41	Excellent
10	RT 20	35.3	150	4.2	Excellent
11	S 40 RT 15	31.2	150	4.80	Excellent

## V. CONCLUSION

The following conclusions may be drawn from the study of the effect of copper slag and discarded rubber tyres replacement on the concrete properties

- The addition of copper slag and rubber tyres has improved the compressive strength, split tensile strength and flexural strength of concrete.
- The results from the ultrasonic pulse velocity tests prove that the copper slag and rubber tyre admixed concrete have excellent quality.
- The results revealed that addition of the copper slag in concrete increases the self-weight of the concrete.
- The compressive strength increased by 36% in copper slag concrete. And when the rubber tyre and copper slag is mixed in definite percentage, the compressive strength increased by 20%
- The flexural strength test on beams results show that the ultimate load carrying capacity of the beam increases by 30% for 38% replacement of copper slag.
- The uses of copper slag as a partial replacement for sand impart strength up to 50% replacement.

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- Water absorption value of copper slag and rubber tyre concrete is lesser than normal concrete.

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