

A Study of Concrete Using Copper Slag as a Partial Replacement of Fine Aggregate

B. Janakiramaiah¹, Dr. B. Ramesh Babu², G. Raghu Yadav³

M.Tech, Dept. of Civil Engineering, ALITS College, Affiliated to JNTUA, AP, India¹

Principal, ALITS College, Affiliated to JNTUA, AP, India²

Dept. of Civil Engineering, ALITS College, Affiliated to JNTUA, AP, India³

ABSTRACT: The paper was focused on the characteristics of copper slag and its effects on the engineering properties of cement, mortars and concrete. Wu et al investigated the mechanical properties of copper slag and reinforced concrete under dynamic compression. The results showed that the dynamic compressive strength of copper slag reinforced concrete generally improved with the increase in amounts of copper slag used as a sand replacement up to 20%, compared with the control concrete, beyond which the strength was reduced. also investigated the mechanical properties of high strength concrete incorporating copper slag as a fine aggregate. The results indicated that the strength of concrete, with less than 40% copper slag replacement, was higher than or equal to that of the control specimen. The microscopic view demonstrated that there were limited differences between the control concrete and the concrete with less than 40% copper slag content.

Based on above investigations, this research study was conducted to investigate the performance of concrete made with copper slag as a partial replacement for fine aggregate. Three test groups were constituted with replacement: 0%, 10%, 30%, and 50% of copper slag withstand in each series.

I. INTRODUCTION

The utilization of industrial waste or secondary materials has encouraged the production of cement and concrete in construction field. Newby-products and waste materials are being generated by various industries. Dumping or disposal waste materials causes environmental and health problems. Therefore, recycling of waste materials is a great potential in concrete industry.

For many years, by-products such as fly ash, silica fume and slag were considered as waste materials. Concrete prepared with such materials showed improvement in workability and durability compared to normal concrete and has been used in the construction of power, chemical plants and under-water structures. Over recent decades, intensive research studies have been carried out to explore all possible reuse methods. Construction waste, blast furnace, steel slag, coal fly ash and bottom ash have been accepted in many places as alternative aggregates in embankment, roads, pavements, foundation and building construction, raw material in the Manufacture of ordinary Portland cement pointed out by Teik thye luin et al.

Copper slag is an industrial by-product material produced from the process of manufacturing copper. For every ton of copper production, about 2.2 tons of copper slag is generated. It has been estimated that approximately 24.6 million tons of slag are generated from the world copper industry (Gorai et al). Although copper slag is widely used in the sandblasting industry and in the manufacturing of abrasive tools, the remainder is disposed of without any further reuse or reclamation. Copper slag possesses mechanical and chemical characteristics that qualify the material to be used in concrete as a partial replacement for Portland cement or as a substitute for aggregates. For example, copper slag has a number of favorable mechanical properties for aggregate use such as excellent soundness characteristics, good abrasion resistance and good stability reported by (Gorai et al). Copper slag also exhibits pozzolanic properties since it contains low CaO. Under activation with NaOH, it can exhibit cementations property and can be used as partial or full replacement for Portland cement.

The utilization of copper slag for applications such as Portland cement replacement in concrete, or as raw material has the dual benefit of eliminating the cost of disposal and lowering the cost of the concrete. The use of copper

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016

slag in the concrete industry as a replacement for cement can have the benefit of reducing the costs of disposal and help in protecting the environment. Despite the fact that several studies have been reported on the effect of copper slag replacement on the properties of Concrete, further investigations are necessary in order to obtain a comprehensive understanding that would provide an engineering base to allow the use of copper slag in concrete.

II. RELATED WORK

Al-Jabri et al (2009) has investigated the performance of high strength concrete (HSC) made with copper slag as a fine aggregate at constant workability and studied the effect of super plasticizer addition on the properties of HSC made with copper slag. Two series of concrete mixtures were prepared with different proportions of copper slag. The first series consisted of six concrete mixtures prepared with different proportions of copper slag at constant workability. The water content was adjusted in each mixture in order to achieve the same workability as that of the control mixture. Twelve concrete mixtures were prepared in the second series. Only the first mixture was prepared using super plasticizer whereas the other eleven mixtures were prepared without using super plasticizer and with different proportions of copper slag used as sand replacement.

Wei wu et al (2010) investigated the mechanical properties of high strength concrete incorporating copper slag as fine aggregate. The workability and strength characteristics were assessed through a series of tests on six different mixing proportions at 20% incremental copper slag by weight replacement of sand from 0% to 100%. A high range water reducing admixture was incorporated to achieve adequate workability. Micro silica with a specific gravity of 2.0 was used to supplement the cementations contenting the mix for high strength requirement. The following conclusions wiredrawn from this study. The results indicated that the strength of concrete with less than 40% copper slag replacement was higher than or equal tithe control specimen.

The microscopic view also suggest that the microstructure of concrete with more than 40% copper slag contains more voids, micro cracks, and capillary channels that accelerate the damage of concrete during loading.

The surface water absorption decreases constantly until 40%of copper slag substitution.

Cajun Shi et al (2008) reviewed the characteristics of copper slag and its effects on the engineering properties of cement, mortars and concrete and they concluded that the utilization of copper slag in cement and concrete provides additional environmental as well as technical benefits for all related industries, particularly in areas where a considerable amount of copper slag is produced. When it is used as a cement replacement or an aggregate replacement, the cement, mortar and concrete containing different forms of copper slag have good performance in comparison with ordinary Portland cement having normal and even higher strength.

III. PROCEDURE

A. CEMENT

An OPC 43 Grade cement was used in this investigation. The quantity required for this work was assessed and the entire quantity was purchased and stored properly in casting yard. The following tests were conducted in accordance with IS codes.

1. Specific gravity (Le – Hotelier flask) (IS: 1727-1967)
2. Standard consistency (IS: 4031 – 1988 Part 4)
3. Initial setting time (IS: 4031 – 1988 Part 5)
4. Final setting time (IS: 4031 – 1988 Part 5)

i. SPECIFIC GRAVITY (LE – CHATELIER FLASK) (IS: 1727-1967)

PROCEDURE

Specific gravity of pozzolanic shall be determined on the material as received, unless otherwise specified.

Fill the flask with kerosene or naphtha to a point on the stem between the zero and the 1 ml mark and replace the stopper. Then immerse the flask in a constant temperature water bath, maintained at about room temperature for sufficient interval to avoid greater than $\pm 0.2^{\circ}\text{C}$ in the temperature of the liquid in the flask. Take the reading of the liquid in the flask.

Introduce a weighed quantity of pozzolanic into flask, taking care that no portion of it adhere to the inside of the flask above the liquid, by slightly vibrating the flask. Replace the stopper and roll the flask in an inclined position to

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016

expel any bubble in the pozzolanic, the level of the liquid will be in its final position at some point of the upper series of graduations. The reading shall be taken after the flasks immersed in the water bath.

Note 1 – A rubber pad on the table may be used when filling or rolling the flask.

Note 2 – The flask may be held in a vertical position in the water bath by means of a burette clamp.

Calculation: The difference between the first and final readings represents the volume of liquid displaced by the weight of cement used in the test. Specific gravity shall be calculated as follows:

$$\text{Specific gravity} = \frac{\text{Weight of pozzolona in g}}{\text{Displaced volume in ml}}$$

ii. STANDARD CONSISTENCY (IS: 4031 – 1988 PART 4)

PROCEDURE

The standard consistency of a cement paste is defined as that consistency which will permit the Vicat plunger G shown in IS : 5513-1 976* to penetrate to a point 5 to 7 mm from the bottom of the Vicat mould when the cement paste is tested as described in 5.2 to 5.4.

Prepare a paste of weighed quantity of Cement with a weighed quantity of potable or distilled water, taking care that the time of gauging is not less than 3 minutes, nor more than 5 min, and the gauging shall be completed before any sign of setting occurs. The gauging time shall be counted from the time of adding water to the dry cement until commencing to fill the mould. Fill the Vicat mould E with this paste, the mould resting upon a non-porous plate. After completely filling the mould, smoothen the surface of the paste, making it level with the top of the mould. The mould may be slightly shaken to expel the air.

Clean appliances shall be used for In filling the mould, the operator's hand on the blade of the gauging trowel shall alone be used. Place the test block in the mould, together with the non-porous resting plate, under the rod bearing the plunger; lower the plunger gently to touch the surface of the test block, and quickly release, allowing it to sink into the paste. This operation shall be carried out immediately after filling the mould. Prepare trial pastes with varying percentages of water and test as described above until the amount of water necessary for making up the standard consistency as defined in 5.1 is found.

iii. Initial setting time (IS: 4031 – 1988 Part 5)

Determination of Initial Setting Time

Place the test block confined in the mould and resting on the non-porous plate, under the rod bearing the needle (C); lower the needle gently until it comes in contact with the surface of the test block and quickly release, allowing it to penetrate into the test block. In the beginning, the needle will completely pierce the test block. Repeat this procedure until the needle, when brought in contact with the test block and released as described above, fails to pierce the block beyond 5.0 ± 0.5 mm measured from the bottom of the mould. The period elapsing between the time when water is added to the cement and the time at which the needle fails to pierce the test block to a point 5.0 ± 0.5 mm measured from the bottom of the mould shall be the initial setting time.

iv. FINAL SETTING TIME (IS: 4031 – 1988 PART 5)

Determination of Final Setting Time

Replace the needle (C) of the Vicat apparatus by the needle with an annular attachment (F). The cement shall be considered as finally set when, upon applying the needle gently to the surface of the test block, the needle makes an impression thereon, while the attachment fails to do so. The period elapsing between the time when water is added to the cement and the time at which the needle makes an impression on the surface of test block while the attachment fails to do so shall be the final setting time. In the event of a scum forming on the surface of the test block, use the underside of the block for the determination.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016

TABLE 1 Test on cement

1	Specific Gravity	3.10
2	Standard consistency	31.5%
3	Initial setting time	57 min
4	Final setting time	4 hour
5	Soundness test (Le- Hotelier's test)	0.95mm

IV. RESULTS

A. FINE AGGREGATE

The fine aggregate used in this investigation was clean river sand and the following tests were carried out on sand as per IS: 2386- 1968 (III).

1. Sieve analysis and fineness modulus
2. Water absorption test on fine aggregate
3. Specific gravity of sand
4. Voids in sand

a. SIEVE ANALYSIS AND FINENESS MODULUS

Sample Taken = 2000 g

Fineness modulus of fine aggregate

$$= \frac{\Sigma \text{ of Cumulative Wt \% of fine aggregate in each sieve}}{100}$$

$$= \frac{445.9}{100} = 4.46$$

Table 2

IS Sieve Size	Wt of fine aggregate retained in each sieve	Cumulative Wt of fine aggregate retained	Cumulative Wt % of fine aggregate retained	Cumulative Wt % of fine aggregate passing
4.75	43	43	2.15	97.85
2.36	56	99	4.95	95.05
1.16	232	331	16.55	83.45
600 μ	579	910	45.5	54.5
300 μ	704	1614	80.7	19.3
150 μ	333	1947	97.35	2.65
90 μ	36	1983	99.15	0.85
75 μ	8	1991	99.55	0.45
Receiver	9	2000	-	100
Total	2000		445.9	

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016

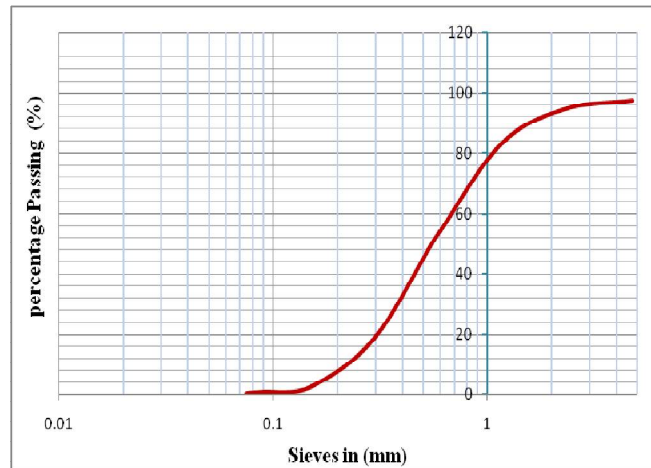


Fig 1 Finesse modulus graph on fine aggregate

TABLE 3 Test on fine aggregate

1	Sieve analysis and fineness modulus	4.46
2	Water absorption test on fine aggregate	1.5%
3	Specific gravity of sand	2.632
4	Voids in sand	38.46%

B. COURSE AGGREGATE

In the present investigation, locally available crushed blue granite stone aggregate of size 20 mm and down, was used and the various tests, carried out on the aggregates, are given below.

1. Sieve analysis for course aggregate
2. Water absorption test on course aggregate
3. Specific gravity of course aggregate
4. Aggregate impact test

SIEVE ANALYSIS FOR COURSE AGGREGATE

Table 4

IS Sieve Size	Wt of course aggregate retained in each sieve	Cumulative Wt of course aggregate retained	Cumulative Wt % of course aggregate retained	Cumulative Wt % of course aggregate passing
20	169	169	16.9	83.1
16	450	619	61.9	38.1
12.5	312	931	93.1	6.9
10	54	985	98.5	1.5
6.3	4	989	98.9	1.1
4.75	6	995	99.5	0.5
Receiver	5	1000	-	-
Total	1000 g			

Finesse modulus of course aggregate

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016

$$\frac{\Sigma \text{ of Cumulative Wt \% of course aggregate in each sieve}}{100} = \frac{468.8}{100} = 4.7$$

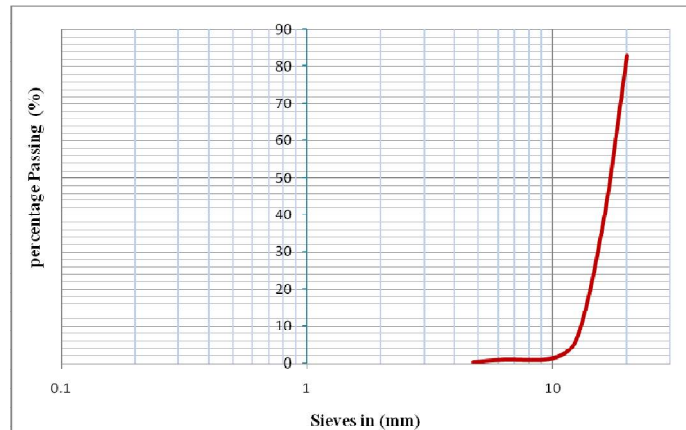


Fig 2 Finesse modulus graph on course aggregate

TABLE 5 Test on course aggregate

1	Sieve analysis for course aggregate	4.7
2	Water absorption test on course aggregate	0.6%
3	Specific gravity of course aggregate	2.623
4	aggregate impact test	71.6%
5	Percentage of voids	39.02%

C. COPPER SLAG

Copper slag is a by-product material produced from the process of manufacturing copper. As the copper settles down in the smelter, it has a higher density, impurities stay in the top layer and then are transported to a water basin with a low temperature for solidification.

SIEVE ANALYSIS REPORT OF COPPER SLAG

Table 6

S.No	Sieve Size mm	Weight Retained gm	Total Weight Retained gm	Total Weight Passing gm	% Passing	% Retained
1	4.75	0	0	500	100	0
2	2.36	29	29	471	94.2	5.8
3	1.18	106	135	365	73	27
4	0.6	154	289	211	42.2	57.8
5	0.3	5	294	206	41.2	58.8
6	0.15	197	491	9	1.8	98.2
7	≤ 0.075	9	500	0	0	100

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016

Fineness modulus of copper slag = 3.476

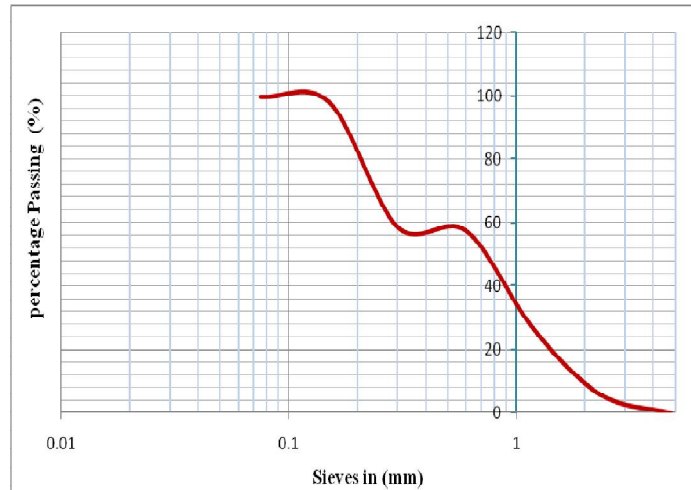


Fig 3 Finesse modulus graph on copper slag

PHYSICAL PROPERTIES OF COPPER SLAG

Copper slag is black glassy and granular in nature and has a similar particle size range like sand. The specific gravity of Indian slag lies between 3.4 and 4.1. The bulk density of copper slag varies between 1.9 to 2.15 kg/m³ which is almost similar to the bulk density of conventional fine aggregate.

TABLE 7 Physical Properties of copper slag

Physical Properties slag	Copper
Particle shape	Irregular
Appearance	Black and glassy
Type	Air cooled
Specific gravity	3.91
Percentage of voids	% 35
Bulk density g/cc	2.08
Fineness modulus	3.47
Angle of internal friction	51° 20'
Ultimate shear stress kg/cm ²	0.4106
Water absorption %	0.16
Moisture content %	0.1
Fineness m ² /kg (after grinding)	125

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016

a. Compressive strength test on concrete cubes

S.NO	Mix Identity	Ultimate load (KN)			Avg ultimate load (KN)			Compressive Strength N/mm ²		
		7 Days	14 Days	28 Days	7 Days	14 Days	28 Days	7 Days	14 Days	28 Days
1	CC	600	600	1010	595	605	980	26.445	26.89	43.55
		590	610	950						
2	S10	690	790	1300	687.5	785	1260	30.55	34.89	56
		685	780	1220						
3	S30	620	700	850	605	725	860	26.885	32.22	38.23
		590	750	870						
4	S50	430	590	690	410	580	700	18.22	25.775	31.11
		390	570	710						

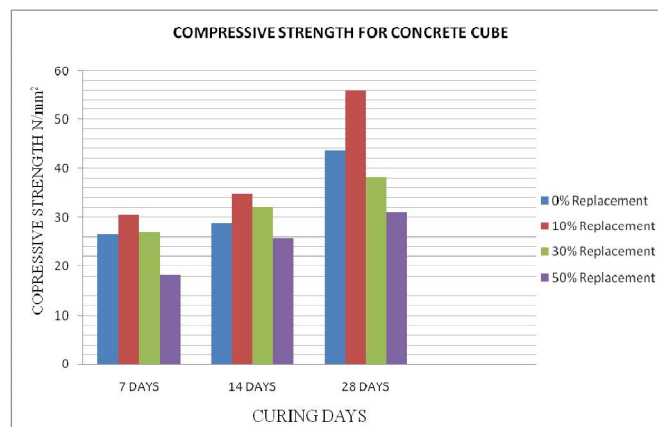


Fig 4 Bar chart in compressive strength for concrete cube

TABLE 9 Split Tensile Strength Test on Concrete Cylinders

S.NO	Mix Identity	Ultimate load (KN)		Yavg ultimate load (KN)		Spilt tensile Strength N/mm ²	
		7 DAYS	28 DAYS	7 DAYS	28 DAYS	7 DAYS	28 DAYS
1	CC	110	200	115	205	1.625	2.9
		120	210				
2	S10	130	220	140	235	1.98	3.326
		150	250				
3	S30	120	210	125	220	1.765	3.11
		130	230				
4	S50	110	190	105	195	1.485	2.755
		100	200				

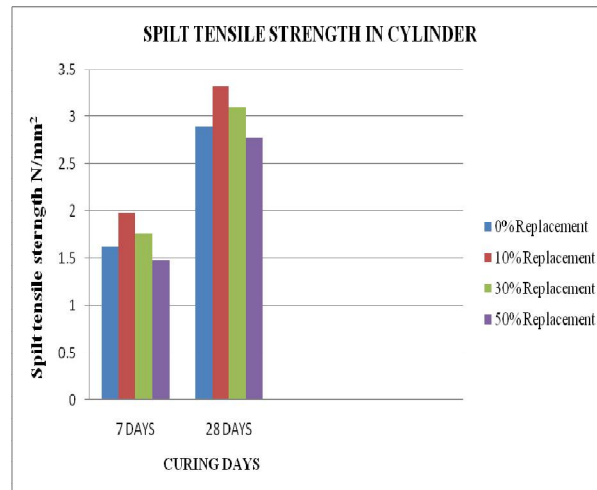


Fig 5 Bar chart for Spilt tensile test in cylinder

V. CONCLUSION

Based on the investigations, the following conclusions were drawn. The utilization of copper slag in concrete provides additional environmental as well as technical benefits for all related industries. Partial replacement of copper slag in fine aggregate and cement reduces the cost of making concrete. Replacement of copper slag (100% replacement with sand) increases the self weight of concrete specimens to the maximum of 15-18%. The results of compressive, split tensile strength test have indicated that the strength of concrete increases with respect to the percentage of copper slag added by the weight of fine aggregate up to 10% (S10). Further additions of copper slag caused reduction in strength due to an increase of free water content in the mix. Utilization of copper slag as Portland cement replacement in concrete and as a cement raw material has the dual benefit of eliminating the costs of disposal and lowering the cost of the concrete. It was observed that, the copper slag replacement for sand is more effective than cement. Accelerated corrosion test reveals that the corrosion rate From these results, it can be concluded that copper slag is a good backfill material than sand and it can be used as backfill in retaining walls.

REFERENCES

- [1] Alnuaimi AS,(2012), "Effects of Copper Slag as a Replacement for Fine Aggregate on the Behavior and Ultimate Strength of Reinforced Concrete Slender Columns", TJER, Vol. 9, No. 2, pp 90-102.
- [2] Ariño Antonio M. ,BarzinMobasher,(1999), "Effect of Ground Copper Slag on Strength and Toughness of Cementitious Mixes", ACI Materials Journal, Vol. 96, No.1, pp 68-74.
- [3] Barnett Stephanie J., Marios N. Soutsos, John H. Bungey, Steve G. Millard,(2007), "Fast-Track Construction with Slag Cement Concrete: Adiabatic Strength Development and Strength Prediction", ACI Materials Journal, V. 104, No. 4, pp 388-396.
- [4] Brindha D. And S. Nagan, (2011), "Durability Studies on Copper Slag Admixed Concrete", Asian Journal of Civil Engineering (Building and Housing), Vol. 12, No. 5, pp563-578.
- [5] Brindha D., Baskaran. T ,Nagan.S (2010), "Assessment of Corrosion and Durability Characteristics of Copper Slag Admixed Concrete", International Journal Of Civil And Structural Engineering Vol 1, No 2, pp-192-211.