ISSN XXXX XXXX © 2018 IJESC

IJESC

Research Article Volume 8 Issue No.6

Flexural Behaviour of Reinforced Concrete Beam by Partially Replacing Pulverized Copper Slag for Cement

Magesh .G[1], Dr.G.Lavanya[2]
PG Student(Structural Engineering)[1], Assistant Professor[2]
Department of Civil Engineering
Anna University Regional Centre, Madurai, Tamil Nadu, India[1]
University College of Engineering, Ramanathapuram, Tamil Nadu, India[2]

Abstract:
All over the world, large quantities of waste materials are causing environmental and health hazards. The world copper production is currently about 14.98 million tons and it is estimated that for every tons of copper produced, about 2.2 tons of copper slag is generated as a waste. Around 24.6 million tons of Copper slag is generated from the world copper industry. Copper slag in an industrial by-product material produced from the process of manufacturing copper. It has been estimated that approximately 24.6 million tons of slag are generated from the world of copper industry. Although copper slag is widely used in sand blasting industry and in the manufacturing of abrasive tools, the remainder is disposed of without any further reuse. Use of copper slag in the concrete industry as a replacement for cement has the benefits of reducing the costs of disposal and helps in protecting the environment. In this paper, an attempt has been made to study the effect of copper slag replaced for cement in reinforced concrete, when compared with the conventional reinforced concrete. It is observed that from the test results that 15% copper slag with 85% cement has promising results when compared to other blends of copper slag and cement. Also, flexure beam test with this optimum mixture of copper slag and cement exhibited flexural behaviour in a ductile manner, as expected.

Keywords: Pulverized Copper Slag, Super plasticizer, Flexural Behaviour

I. INTRODUCTION

Copper slag is a by-product obtained during matte smelting and refining of copper. The common management options for copper slag are recycling, recovering of metal, production of value added products such as abrasive tools, roofing granules, cutting tools, abrasive, tiles, glass, road-base construction, railroad ballast, asphalt pavements. Despite increasing rate of reusing copper slag, the huge amount of its annual production is disposed in dumps or stockpiles to date. One of the greatest potential applications for reusing copper slag is in cement and concrete production. Many researchers have investigated the use of copper slag in the production of cement, mortar and concrete as raw materials for clinker, cement replacement, coarse and fine aggregates. The use of copper slag in cement and concrete provides potential environmental as well as economic benefits for all related industries, particularly in areas where a considerable amount of copper slag is produced. In India, there is lot of copper producing plant and natural stone crushing plants are available.At present, across the world around 33 tonnes of slag is generated while in India three copper producers Sterlite, Birla Copper and Hindustan Copper produce around 6-6.5 tonnes of slag at different sites. With increasing scarcity of river sand and natural aggregates across the country, construction sector is under tremendous pressure to explore alternative to these basic construction materials to meeting growing demand of infrastructure demands.In states like Tamil Nadu, Kerala, Maharashtra and Gujarat, sand mining in rivers has already been banned owing to its disastrous impact ecology. Therefore, slag has a big potential of getting developed as a suitable alternative material in the conventional concrete applications. Copperslag is highly stable and non-leachable in nature. The utility of copper slag as alternative material for other industrial / sectoral application has been vastly explored in the last one decade.

II LITERATURE REVIEW

Shanmuganathan et al., (2007) studied the environmental hazard from the viewpoint of leaching of heavy metals from the slag and its long-term stability in extreme environmental conditions. He has reported that heavy metals present in the slag are very stable and have poor leachability. They have suggested that the slag is safe to be considered for use in a wide variety of applications such as for Portland cement, building materials such as tiles and bituminous pavement constructions. The slag samples are non-toxic and pose no environmental hazard. **Chavan & Kulkarni (2013)** conducted experimental investigations to study the effect of using copper slag as a replacement of fine aggregate on the strength properties. The authors have concluded that maximum compressive strength of concrete increased by 55% at 40% replacement of fine aggregate by copper slag and flexural strength increased by 14 % for 40 % replacement. **Wei wu et al (2010)** investigated the mechanical properties of high strength concrete replacing fine aggregate with copper slag. Micro silica was used to supplement the cementitious content in the mix for high strength requirement. They observed that when copper slag was used to replace fine aggregate, upto 40% copper slag replacement, the strength of concrete was increases while the surface water absorption decreases. They have also observed that when more than 40% of copper slag is used, the microstructure of concrete contains more voids, micro cracks, and capillary channels which accelerate the damage of concrete during loading. **Al-Jabri et al (2009, 2011)** investigated the performance of high strength concrete made with copper slag as a replacement for fine aggregate at constant workability and studied the effect of super plasticizer addition on the properties of High Strength Concrete made with copper slag. They observed that the water demand reduced by about 22% for 100% copper slag replacement. The strength and durability of High Strength Concrete improved with the increase in the content of copper slag of upto 50%. However, further additions of copper slag caused reduction in the strength due to increase in the free water content in the mix. Also, the strength and durability characteristics of High Strength Concrete were adversely affected by the absence of the super plasticizer from the concrete paste despite the improvement in the concrete strength with the increase of copper content. The test results also show that there is a slight increase in the density of nearly 5% with the increase of copper slag content, whereas the workability increased rapidly with increase in copper slag percentage.

Caijun Shi et al (2008) reviewed the effect of copper slag on the Engineering properties of cement mortars and concrete. They reported that the utilization of copper slag in cement mortar and concrete is very effective and beneficial for all related industries, particularly in areas where a considerable amount of copper slag is produced. It proved both environmental as well as technical benefits. They observed that there was more than 70% improvement in the compressive strength of mortars with 50% copper slag substitution. Most of the researchers have reported the effect of copper slag as a replacement for fine aggregate, in their experimental investigations. Hence, an attempt has been made to study the effect of pulverized copper slag replaced by cement in this paper.

III. MIX PROPORTIONS

3.1 Mix Proportions

Based on the various literature reviews, it was proposed to find the optimum proportion of Copper slag in the high strength concrete. The mix proportions of the materials listed in Table 1 is attempted. For easy identification, the specimens were designated in the format PCSx where "PCS" stands for Pulverized Copper Slag, "x" is the percentage of Pulverized Copper Slag. As an example, PCS10 represents Pulverized Copper Slag 10% and Cement 90%. Control Specimen (without copper slag) is designated as "CS". Copper slag (pulverized) used in this study is procured from M/s. Astrra Chemicals, Chennai. Superplasticizer used in this study is manufactured by FOSROC Chemicals India (P) Ltd. and is procured from local supplier M/s Velavan Chemicals, Madurai.

Table.1. Mix proportions

S.No.	Mix ID	Cement (%)	Copper Slag (%)
1	CS	100	0
2	PCS5	95	5
3	PCS10	90	10
4	PCS15	85	15
5	PCS20	80	20

3.2 Mix Design

The mix design is based on Indian Standard Code IS:10262-2009. The mix ratio arrived is 1:2.33:3.22 with water cement ratio 0.40. Superplasticizer is added at the rate of 2% of cementitious materials to improve the workability of the concrete and as suggested by the IS Code.

IV. EXPERIMENTAL PROGRAM

4.1 Specimen Details

Concrete cubes are cast in the standard cube size of 0.15m x 0.15m x 0.15m and tested in the compression testing machine of 2000 kN capacity. The cubes were tested as per IS: 516-1959. Similarly, cylinders of size 0.30 m height and 0.15 m diameter is tested in compression testing machine for their split tensile strength as per IS:5816-1970. Prisms were tested under single point load in Universal Testing Machine of 40 T capacity, for their flexural strength (Modulus of Rupture). Before casting the specimens, all the moulds were thoroughly cleaned to remove any dirt's and oiled with waste-oil, to prevent sticking of concrete with the mould. The casting and testing of the specimens is shown in figure1 & 2. Pulverized Copper Slag and Super plasticizer were added as per stipulated percentages. For each mix, 3 cubes, 3 cylinders and 3 prisms were cast and tested. All the specimens that were cast are demoulded after 24 hours. The specimens are then allowed to be cured in a water sump for 28 days from the day of casting of specimens.

Figure. 1. casting of specimens

Figure.2. Testing Of Specimen

V. RESULTS AND DISCUSSIONS

5.1 Compressive Strength

The compressive strength results of all the cube specimens (150 mm x 150 mm x 150 mm in size) cast and tested are tabulated in table 2.The tests were conducted as per Indian Standards IS:516-1959. Figure 3 shows the comparision of compressive strength of all the specimens graphically. The compressive strength is calculated using the relation $f_c = \frac{P}{A}$N/mm^2, where P is the applied load and A is the area of cross section of the cube. From table 2,it can be observed that the mix PCS15 resulted in highest compressive strength at 28 days (56.44 MPa), which is 69.80% more than the control specimen CS (33.24 MPa). Similarly, it can be observed from table 2 that as the percentage of Copper slag increases, the compressive strength also increases. From the results, the optimum mix of Copper slag can be fixed as PCS15, since it achieved highest compressive strength, when compared to all the other specimens.

Table.2. Compressive strength test results

S.No.	Mix Designation	Average Compressive Strength (N/mm^2)	Percentage increase/decrease compared to Control Specimen (CS)
1	CS	33.24	-
2	PCS5	36.13	+8.69
3	PCS10	47.24	+42.14
4	PCS15	56.44	+69.80
5	PCS20	45.60	+37.18

Figure.3. Comparision of Compressive Strengths

5.2 Split Tensile Strength

Similar to the compressive strength, the split tensile strength of all the specimens is determined as per IS:5816-1999. Table 3 shows the results of split tensile strength of all the cylinder specimens. The split tensile strength is calculated using the formula $f_{st} = \frac{2P}{\pi dl}$ N/mm^{2}where P is the applied load, *d* (150 mm) is the diameter of the cylinder and *l* is the height of the specimen (300 mm).

Table.3.Split Tensile Strength Test Results

S.No.	Mix Designation	Average Split Strength (N/mm^2)	Percentage increase/decrease compared to Control Specimen (CS)
1	CS	3.25	-
2	PCS5	3.79	+16.62
3	PCS10	3.85	+18.46
4	PCS15	4.68	+44.00
5	PCS20	4.13	+27.08

From table 3, it can be observed that the mix PCS15 resulted in highest split tensile strength at 28 days (4.68 MPa), which is 44% more than the control specimen CS (3.25 MPa). Similarly, it can be observed from table 4 that as the percentage of Copper slag increases, the split tensile strength also increases upto 15% Copper Slag blend. Thereafter, the split tensile strength decreased as in the case of compressive strength. From the results, the optimum mix of Copper slag can be fixed as PCS15, since it achieved highest split tensile strength, when compared to all the other specimens. The comparision of split tensile strength is graphically shown in figure 4.

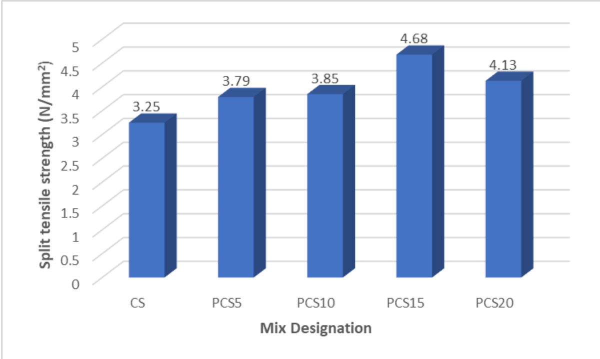

Figure.4. comparision of split tensile strength

5.3 Flexural Strength Test

The flexure strength of all the prisms cast were determined as per Indian Standard Code IS:516-1959. The results of all the prism specimens cast and tested is tabulated in table 4. Figure 5 shows the comparitive flexure strengths of all the prisms when compared to control specimen. The flexural strength of the specimens are calculated from the relation $f_{cr} = \frac{3Pa}{bd^2}$,where P is the applied load, a is the distance between the flexural crack and the nearest support,b(100 mm) and d (100 mm) are the breadth and depth of the specimen respectively. It is measured in N/mm^2.

Table.4. Flexure strength test results

S.No.	Mix Designation	Average Flexure Strength (N/mm^2)	Percentage increase/decrease compared to Control Specimen (CS)
1	CS	3.02	-
2	PCS5	3.57	18.21
3	PCS10	3.74	23.84
4	PCS15	5.07	67.88
5	PCS20	4.27	41.39

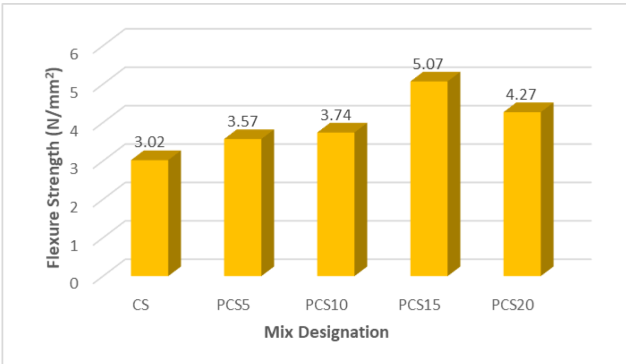

Figure.5. Comparision of Flexure Strength

From table 4, it can be observed that the mix PCS15 resulted in highest flexure strength at 28 days (5.07 MPa), which is 67.88% more than the control specimen CS (3.02 MPa). Similarly, it can be observed from table 5 that as the percentage of Copper slag increases, the flexure strength also increases upto 15% Copper Slag blend. Thereafter, the flexure strength decreased as in the case of compressive strength and split tensile strength. From the results, the optimum mix of Copper slag can be fixed as PCS15, since it achieved highest flexure strength, when compared to all the other specimens. The comparision of flexure strength is graphically shown in figure 5.From all the test results viz., compressive test, split tensile strength test, flexure strength test, since the specimen PCS15 achieved highest strength, 15% of copper slang blended with cement can be fixed as the optimum mix.

5.4 Flexural Behaviour

A flexure beam was cast and tested for its flexural behavior based on the optimum mix fixed (PCS15). The size of the reinforced concrete beam is 1600 mm in length, 100 mm in width and 150 mm in depth. It was reinforced with 2#8 mm diameter bars at top and bottom. 8 mm diameter bars at 100 mm c/c were used as the stirrups. The experimental setup is shown in fig. 6. To measure the central deflection of the beam, a dial gauge with maximum capacity of 50mm deflection with 0.01mm least count is fixed at the bottom central portion of the beam.

Figure.6. experimental setup

The beam was white-washed all-round to clearly view the cracks. The load was applied through a manually operated hydraulic jack at a uniform rate of 0.5T in steps. The dial gage readings were carefully noted once the load reaches every 0.5 T. The ultimate load carrying capacity achieved by the beam was 40 kN.The beam was tested until failure to observe the effect of copper slag on the flexural response of reinforced concrete beam. The beam failed in flexure and it was a ductile failure. The failure occurred in-between the load points in the flexure zone. The failure in the beam accompanied with the formation of flexural cracks from the soffit of the beam. As the load increases, the cracks were clearly visible, and they extended from the bottom of the beam towards the point of loading. The top compression layers were found crushed in-between the load points at the time of final loading stages. The load deflection behaviour was linear up to elastic stage and thereafter, it followed non-linear behaviour upto ultimate load. The crushing sound of the beam was clearly heard as the load progressively increases. The ultimate deflection observed was 18 mm. Figure 7 shows the load-deflection response of the beam. Figure 8 shows the ductile failure modes of the beam.

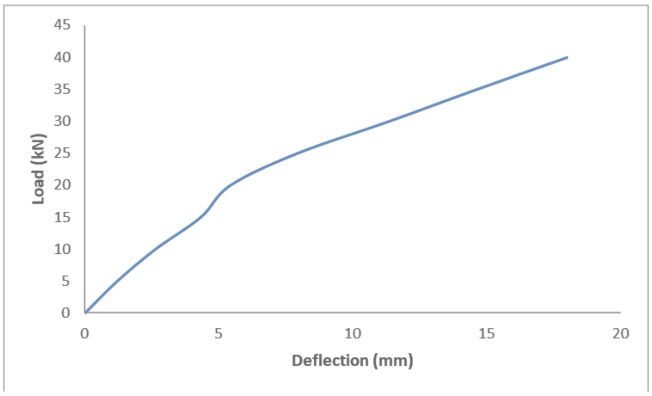

Figure.7. Load-Deflection Behaviour

Figure.8. failure mode of the beam

VI. CONCLUSIONS

From the experimental investigations carried out in this study, the following conclusions were drawn:

1. The compressive strength of the concrete mixed with 15% copper slag and 85% cement achieved higher compressive strength when compared to other combinations. The specimen PCS15 achieved highest compressive strength of 56.44 N/mm^2, which is 69.80 % higher than the concrete without PCS.
2. Similar to the Compressive Strength, the split tensile strength of the concrete mixed with 15% PCS and 85% Cement achieved higher split tensile strength when compared to other combinations of PCS and Cement. The specimen PCS15 achieved highest split tensile strength of 4.68 N/mm^2, which is 44% higher than the concrete without PCS.
3. As in the case of Compressive Strength and Split Tensile Strength the specimen PCS15 experienced highest flexure strength when compared to other combinations of PCS and Cement. It achieved highest flexure strength of 2.53 N/mm^2, which is 67.33 % higher than the concrete without PCS.
4. The flexural behaviour of RC beam mixed with 15% PCS experienced better load-deflection response as expected. The beam failed in a ductile manner with concrete crushing at the top compression zone with separation of concrete layers and achieving an ultimate load of 40 kN with maximum deflection of 30 mm.
5. Based on the experimental investigations done in this project, the properties of concrete specimens mixed with various ratio of Pulverized Copper Slag and OPC, it is recommended to mix 15% PCS and 85% cement to get maximum strength of the high strength concrete.
6. Further studies are needed to ascertain the strength of the concrete specimens with other types of fibers.

VII. REFERENCES

[1].Shanmuganathan.P, Lakshmipathiraj,P S.Srikanth, A.L. Nachiappan, A. Sumathy, "Toxicity characterization and long-term stability studies on copper slag from the ISASMELT process", Resources, Conservation & Recycling, Sept 2007, 52, pp. 601-611.

[2].Chavan R, D B Kulkarni, "Performance of Copper Slag on Strength Properties as Partial Replace of Fine Aggregate In Concrete Mix Design", International Journal of Advanced Engineering Research and Studies, July-Sept., 2013, pp. 95-98.

[3].Wu.W, Zhang.W, and Ma.G. "Optimum content of copper slag as a fine aggregate in high strength concrete", Journal of Material Design, Vol.31, No.6, pp. 2878-2883, 2010.

[4].Al-Jabri, K. and Makoto Hisada. "Copper slag as sand replacement for high performance concrete", Journal of Cement & Concrete Composites, Vol. 31, pp. 483- 488, 2009.

[5].Al-Jabri, K.S., Abdullah, H., Al-Saidy, Ramzi Taha. "Effect of copper slag as a fine aggregate on the properties of cement mortars and concrete", Journal of Construction and Building Materials, Vol. 25, pp. 933-938, 2011.

[6].Caijun Shi, Christian Meyer, and Ali Behnood, "Utilization of copper slag in cement and concrete", Resources Conservation and Recycling, Vol. 52, pp. 1115-1120, 2008.

[7].Teik Thye Luin, and Chu J. "Use of spent copper slag for land reclamation", Waste Management and Research, Vol. 24, pp. 67-73, 2004.

[8].Byung Sik Chun, Du Hee Park, and Hun Chul Jung "A Study on the Application of Copper Slag as a Sand Substitute of Sand Compaction Pile", Proceedings of 15th International Offshore and Polar Engineering Conference, 2005.

[9].Mobasher, B., Devaguptapu, R. and Arino, A.M. "Effect of copper slag on the hydration of blended cementitious mixtures", Proceedings of the ASCE Materials Engineering Conference, pp. 1677-1686, 1996.

[10].Sioulas, Z.B. and Sanjayan, J.G. "Hydration temperatures in large high-strength concrete columns incorporating slag", Journal of Cement and Concrete Research, Vol.30, No. 11, pp. 1791-1799, 2000.

[11].Washington Almeida, Moura Jardel, Pereira Gonc, and Monica Batista Leite Lima, "Copper slag waste as a supplementary cementing material to concrete", Journal of Material Science, Vol.42, pp. 2226-2230, 2007.

[12].Ayano Toshiki, Kuramoto Osamu, and Sakata Kenji, "Concrete with copper slag fine aggregate", Society of Materials Science, Vol. 49, pp. 1097-1102, 2000.

[13].Bipra Gorai,Jana, R. K. and Premchand, "Characteristics and utilisation of copper slag-a review", Resources, Conservation and Recycling, Vol. 39, No. 4, pp. 299-313, 2002.

[14].Mostafa Khanzadi, Ali Behnood, "Mechanical properties of high-strength concrete incorporating copper slag as coarse aggregate", Journal of Construction and Building Materials, 2009, Vol. 23, 2183–2188.

[15].Goni, S., Lorenzo, M. P. and Guerrero, A. "Activation of Pozzolanic Reaction of Hydrated Portland Cement Fly Ash Pastes in Sulfate Solution", Journal of the American Ceramic Society, Vol.85, No.12, pp.3071-3075, 2002.

[16].Nataraja, M. C. Concrete mix design using copper slag as fine aggregate. International journal of Civil E]ngineering, 5(9), 90-99, 2014.

[17].Rose, D.A, "Performance of Copper Slag on Strength and Durability Properties as Partial Replacement of Fine Aggregate in Concrete", International Journal of Emerging Technology and Advanced Engineering, 5(1), 434-437, 2015.

[18].Singh, H. Use of copper slag as fine aggregate - A case study, International Journal of Innovations in Engineering Research and Technology,2(5), 1-7, 2015.

[19].Shi, C., "Utilization of copper slag in cement and concrete", Resources, Conservation and Recycling, 52, 1115–1120, 2008.

[20].Arivalagan, S., "Experimental Study on the Flexural Behavior of Reinforced Concrete Beams as Replacement of Copper Slag as Fine Aggregate", Journal of Civil Engineering and Urbanism, 3(4), 176-182, 2013.

[21].Maheswari, M., "Mechanical and Durability Properties of RC Beams Using Copper Slag as Fine Aggregate in Concrete", International Research Journal of Engineering and Technology, 3(3), 2016.

[22].Madhavi,T.C, "Effect of Copper Slag on the Mechanical Strengths of Concrete", International Journal of ChemTech Research, 8(12), 442-449, 2015.

[23].Patil, M. V., "Performance of Copper Slag as Sand Replacement in Concrete", International Journal of Applied Engineering Research, 11(6), 4349-4353, 2016.

[24].Zerdi, T.A., "Experimental Investigation on Properties of Concrete by Replacement Copper Slag for Fine Aggregate", Global Journal for Research Analysis, 5(5), 67-69, 2016.

[25].Caliskan S. and A. Behnood, "Recycling copper slag as coarse aggre-gate: hardened properties of concrete", Proceedings of 7th International Conference on Concrete Technology in Developing Countries, Malaysia (2004), pp. 91–98.

[26].Zong L., "The replacement of granulated copper slag for sand concrete", Journal of Qingdao Inst Architect Eng 24 (2), pp. 20–22, 2003.

[27].Rojas Isabel Sanchez de, Julian Rivera, Moises Frıas and Felix Marın, "Review Use of recycled copper slag M for blended cements", Journal of Chemical Technology and Biotechnology, No.83, pp:209–217, 2008.

[28].Khanzadi M. and A. Behnood, "Mechanical properties of high-strength concrete incorporating copper slag as coarse aggregate", Construction & Building Materials, No. 23, pp. 2183–2188, 2009.