

Replacement of Fine Aggregate by Using Copper Slag

Niraj Ashok Burge, P.M.Kulkarni

M. E Students, Department of Civil Engineering, KJEI'S Trinity College of Engineering and Research, Pune, India

Professor, Department of Civil Engineering, KJEI'S Trinity College of Engineering and Research, Pune, India

ABSTRACT: This paper presents the experimental investigation of properties of concrete using copper slag as replacement material of fine aggregates to increase the hardened concrete properties such as compressive strength, split tensile strength, flexural strength and ultrasonic pulse velocity of concrete. The present study encouraged the use of industrial by-product or waste copper slag as replacement material of fine aggregates in concrete. Mix proportion has to be done for M25 grade of concrete with water cement ratio 0.50. The fine aggregate is replaced with copper slag in proportions of 0%, 20%, 30%, 40%, 50%, 60%, 80%, and 100%. Tests were performed for properties of fresh concrete and hardened concrete. All concrete specimens were cured for 28 days before compression strength test, split tensile strength test, flexural strength test and ultrasonic pulse velocity test. The results indicate that workability and density of concrete increases significantly with the increase of copper slag content in concrete mixes. The results also demonstrated that the highest compressive strength, split tensile strength and flexural strength obtained were 41.53 N/mm², 3.86 N/mm² and 5.42 N/mm² for 40% replacement of fine aggregate by copper slag as compared to control mixture. The ultrasonic pulse velocity test indicated the excellent quality of concrete at all percentage replacement level. Therefore, it is recommended that 40% of copper slag can be use as replacement of fine aggregates. Also on the basis of obtained results the empirical relationships between the mechanical properties of concrete were established.

KEYWORDS: Cement, Copper slag, Fine aggregate, concrete, UPV, compressive strength, split tensile strength, flexural strength.

I. INTRODUCTION

1.1 General

The utilization of industrial waste or secondary materials has encouraged the production of cement and concrete in construction field. New by-products and waste materials are being generated by various industries. Dumping or disposal of 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 copper 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.

1.2 Objective & Scope of Presented Investigation

1. To find the optimum proportion of copper slag that can be used as a replacement/ substitute material for fine aggregate.
2. To evaluate the effect of copper slag replacement on the workability and density of concrete.
3. To find the compressive strength, split tensile strength, flexural strength and ultrasonic pulse velocity of copper slag replaced concrete specimens.
4. To propose an empirical relationship between mechanical properties of concrete.

1.3 Brief Conclusion

The present study investigated the effectiveness of using copper slag (a waste material obtained from bhosari MIDC, Pune) for the partial or full replacement of sand in concrete. Different tests are performed on the concrete in fresh and hardened state and results are explained. The conclusions based on entire experimental work are summarized as follows:

1. 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 reduces the cost of making concrete.

2. Water absorption of copper slag was 0.40% compared with 1.21% for sand. Therefore, the workability of concrete increases significantly with the increase of copper slag content in concrete mixes. This was attributed to the low water absorption and glassy surface of copper slag.
3. As the percentage of copper slag in design mix as replacement increases, the density of hardened concrete observed to be increased. The density was increased by 5.97% when replacement of fine aggregate by 100% copper slag. This is because weight of concrete increases with copper slag.
4. Maximum Compressive strength of concrete increased by 46% at 40% replacement of fine aggregate by copper slag.
5. Maximum Split Tensile strength of concrete increased by 30.5% at 40% replacement of fine aggregate by copper slag.
6. Replacement of copper slag up to 60% will increase the Compressive and Split Tensile strength than control mix concrete strength, but beyond 60% replacement the strength started to reduce due to an increase of free water content in the mix. The Compressive and Split Tensile strength at 100 % replacement is reduced by 17.15% and 18.06% at 28 days.

1.4 Scarcity of sand and sources

Sand constitutes nearly 40% of raw material used for any of the construction projects - residential, commercial or infrastructure. Loose and granular in nature, it is omnipresent which made it an indispensable element of our living structures. From building infrastructure to making glass, silicon chips or even toothpaste it has something to contribute. A sudden surge in the infrastructure developments and demand for homes over the last couple of decades or so, has increased its usage and just proportionally – demand. In fact this incessant demand has made it one of the most consumed raw materials in the world, after water (of course). **River Sand Rate in Pune region is about Rs 7,000/ - 13000 Per Brass**

Solutions:

1. **M-sand:** Manufactured sand (M-sand) has emerged an alternative to sand in last few years. It is manufactured by crushing of rocks, making it into a fine powder which is used as sand plastering. M-sand has less wastage in comparison to river sand which used to have a minimum of 20 – 30% wastage. Pilferages are very minimal in the M-sand process in comparison to the conventional process.
2. **Gypsum plaster:** Replaces sand cement plaster with gypsum plaster for internal plastering. If gypsum plaster is used right from the initial phase of the project, it can reduce the overall usage of sand in the project substantially.
3. **Constech:** Constech (construction technology) like advanced pre-cast and Mivan has played a pivotal role in reducing usage of raw materials, particularly sand while constructing a project. The above alternatives to natural sand along with latest construction technology have been instrumental in addressing the scarcity of sand. With the growing acceptance of the sand alternatives and adoption of Constech by numerous builders, the usage of sand in construction will gradually be negligible. Even from a cost factor these alternatives are almost at par with sand.
4. **Environment friendly:** It is the responsibility of every developer to comply and adopt green sustainable practices to ensure judicious usage of sand and other natural resources.
5. **Spreading awareness:** As a fraternity we should work closely with government and other NGO's to conserve the natural resources and reduce the misuse of sand. Industry bodies like CREDAI can initiate awareness drives and educate the sector on methods to use alternatives, to conserve and eventually protect. With RERA and GST in the picture now, the market is witnessing a consolidation of sorts. In a couple of years from only serious and responsible builders will operate in the market.

III. REVIEW OF LITERATURE

2.1 Historical Background

Concrete is a most versatile construction material because it is designed to withstand the harsh environments. Engineers are continually pushing the limits to improve its performance with the help of innovative chemical admixtures and supplementary materials. These materials are majority by products from other processes. The use of these byproducts not only helps to utilize these waste materials but also enhances the properties of concrete in fresh and hydrated states. The usage of industrial by-products especially industrial slags in making of concrete is an important study of worldwide interest. Many researchers have investigated the possible use of copper slag as a concrete aggregate. For this investigation, some of the important literatures were reviewed and presented briefly.

1.2 Literatures Review of Reference Paper

1. Al-Jabri et al (2009) [1] 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.

2. Wei wu et al (2010) [2] 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 cementitious content in the mix for high strength requirement.

3. Caijun Shi et al (2008) [3] 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.

4. Teik-Thye Lim and Chu (2006) [4] conducted a study on the feasibility of using spent copper slag as fill material in land reclamation. The physical and geotechnical properties of the spent copper slag were first assessed by laboratory tests, including hydraulic conductivity and shear strength tests. The physical and geotechnical properties were compared with those of conventional fill materials such as sands. The potential environmental impacts associated with the use of the spent copper slag for land reclamation were also evaluated by conducting laboratory tests including pH and Eh measurements, batch-leaching tests, acid neutralization capacity determination and monitoring of long-term dissolution of the material. The spent copper slag was slightly alkaline, with pH 8.4 at a solid /water ratio of 1:1. The batch-leaching test results showed that the concentrations of the regulated heavy metals leached from the material at pH 5.0. They were significantly lower than the maximum concentration for their toxicity limits referred by United States Toxicity Characteristic Leaching Procedure. They finally suggested that the spent copper slag was a good fill material and it can be used as a fill material for land reclamation.

5. D.Brindhal et al (2011) [5] investigated the results of an experimental study on various corrosion and durability tests on concrete containing copper slag as partial replacement of sand and cement. For this research work , M20 grade concrete was used and the tests were conducted for various proportions of copper slag replacement with sand of 0%, 20%, 40%, and 60%, cement of 0%, 5%, 15% and 20% and combination of both (60% sand + 40% copper slag for fine aggregate and 85% cement+15% copper slag for cement) in concrete. Concrete mixes were evaluated for compressive strength, split tensile strength, acid and sulphate attack test, RCPT Test, Ultrasonic pulse velocity test etc. The result showed that, the compressive, split tensile strength test have indicated that the strength of concrete increases with respect to the percentage of slag added by weight of fine aggregate up to 40% of additions and 15% of cement. Water absorption of S40 copper slag concrete specimens is 22% lower than the controlled specimens. Water permeability in concrete reduced up to 40% replacement of copper slag with that of sand. The addition of copper slag for the replacement of sand shows higher resistance against Sulphate attack whereas addition of copper slag for the replacement of cement gives lower resistance.

6. Meenakshi Sudarvizhi.S and Ilangovan. R (2011) [6] investigated the Performance of Copper slag and ferrous slag as partial replacement of sand in Concrete. This work reports an experimental procedure to investigate the effect of using CS and FS as partial replacement of sand. The strength characteristics of conventional concrete and slag concrete such as compressive strength, tensile strength were found .Six series of concrete mixtures were prepared with different proportions of CS and FS ranging from 0% to 100%. The test results of concrete were obtained by adding CS and FS to sand in various percentages ranging from 0%, 20%. 40%, 60%, 80% and 100%. All specimens were cured for 7, 28, 60 & 90 days before compression strength test and splitting tensile test. The results indicate that workability increases with increase in CS and FS percentage. The highest compressive strength obtained was 46MPa (for 100% replacement) and the corresponding strength for control mix was 30MPa. The integrated approach of working on safe disposal and

utilization can lead to advantageous effects on the ecology and environmental also. It has been observed that upto 80% replacement, CS and FS can be effectively used as replacement for fine aggregate.

7. Mostafa Khanzadi and Ali Behnood (2009) [7] presented the results of a study undertaken to investigate the feasibility of using copper slag as coarse aggregates in high-strength concrete. The effects of replacing limestone coarse aggregate by copper slag coarse aggregate on the compressive strength, splitting tensile strength and rebound hammer values of high-strength concretes are evaluated in this work. Concrete mixtures containing different levels of silica fume were prepared with water to cementitious materials ratios of 0.40, 0.35 and 0.30. The percentages of the cement replacements by silica fume were 0%, 6% and 10%. The use of copper slag aggregate compared to limestone aggregate resulted in a 28-day compressive strength increase of about 10–15% and a splitting tensile strength increase of 10–18%. It can be concluded from the results of this study that using copper slag as coarse aggregate in high-strength concrete is technically possible and useful.

8. Basil Johny et al (2014) [8] conducted study on the feasibility of using ground granulated blast furnace slag as an alternative for cement and recycled coarse aggregate for natural coarse aggregate. Experimental investigation is carried out with a conventional M30 mix, mixes by replacing with 40 percent, 50 percent and 60 percent of cement with ground granulated blast furnace slag (GGBS). Mix with 50 percent of cement when replaced with GGBS gave better performance compared to M30 conventional mix when tested for fresh and mechanical properties. For further study mix was made with 50 percent replacement of cement with slag and 50 percent replacement of coarse aggregate with recycled coarse aggregate. Its fresh and mechanical properties were then compared with M30 mix. Fresh properties were studied using slump test and compaction factor test. Mechanical properties studied were compressive, flexural and splitting tensile strengths. Mix with GGBS and recycled aggregates gave a satisfactory performance compared to M30 conventional mix.

9. Najimi et al (2011) [9] investigated the performance of copper slag contained concrete in sulphate solution. In this regard, an experimental study including expansion measurements, compressive strength degradation and micro structural analysis were conducted in sulphate solution on concretes. This was made by replacing 0%, 5%, 10% and 15% of cement with copper slag waste. The results of this study emphasized the effectiveness of copper slag replacement in improving the concrete resistance against sulphate attack.

10. Amit S. Kharade et al (2013) [10] presents the results of an experimental investigation carried out to evaluate the mechanical properties of concrete mixtures in which fine aggregate (sand) was replaced with Copper Slag. The fine aggregates (sand) was replaced with percentages ranging from 0% (for the control mixture) to 100% of Copper Slag by weight. Tests were performed for properties of fresh concrete and Hardened Concrete. Compressive strength and Flexural strength were determined at 7, 28 and 56days. The results indicate that workability increases with increase in Copper Slag percentage. Test results indicate significant improvement in the strength properties of plain concrete by the inclusion of up to 80% Copper slag as replacement of fine aggregate (sand), and can be effectively used in structural concrete. Also as percentage of Copper Slag increased the density of concrete increased. The workability of concrete increased with increase in percentage of copper slag.

III. PROPERTIES OF COPPER SLAG

3.1 Physical Properties

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. The free moisture content present in slag was found to be less than 0.5%. Table 4.3, 4.4 and 4.5 shows physical properties of copper slag.



1. Specific gravity:

Table 3.1:- Specific gravity of Copper Slag

Notation	Description of work	Weight (gm)
A	Weight of Saturated Surface Dry sample	500
B	Weight of pycnometer + copper slag + water	1897
C	Weight of pycnometer + water	1530
D	Weight of oven dried sample	498

2. Fineness Modulus :

Table 3.2:- Fineness Modulus of Copper Slag

Sr. No	IS Sieves	Wt. Retained (gm)	Percent age Wt. Retained (%)	Cumulative Percentage Wt. Retained (%)	Cumulative Percentage Wt. Passing(%)
1	4.75	3	0.3	0.3	99.7
2	2.36	20	2	2.3	97.7
3	1.18	205	20.5	22.8	77.2
4	600	451	45.1	67.9	32.1
5	300	281	28.1	96	4
6	150	37	3.7	99.7	0.3
7	75	3	0.3	100	0
8	PAN	0	0	100	0

Fineness Modulus =
 Sum of cumulative % of Wt. Retained from 4.75 mm to 150µm/100
 =289/100
 =2.89

3.2 Uses of Fine Aggregate

The fine aggregate used in this study is river sand conforming to grading zone II Table 1 of IS 383 were procured from local river in Maharashtra [10]. The coarse aggregate used in this study is of angular in shape and the maximum nominal size of coarse aggregate is 20 mm and it is Conforming to Table 2 of IS 383 and which is taken from Pune area [10]. Some physical properties of fine aggregate and coarse aggregate are mentioned in Table 2 below.



Table 3.3: Physical properties of fine aggregate and coarse aggregate

Sr. No.	Test	Fine Aggregate	Coarse Aggregate
1	Specific gravity	2.50	2.68
2	Fineness modulus	2.91	7.17
3	Water absorption (%)	1.21	1.297

3.3 Advantages

1. Reduces the construction cost due to saving in material cost.
2. Reduces the heat of hydration.
3. Refinement of pore pressure.
4. Reduces permeability.
5. Reduces the demand for primary natural resources.
6. Reduces the environmental impact due to quarrying and aggregate mining.

IV. EXPERIMENTAL INVESTIGATION

4.1 Study of basic Prop of used Cement

Cement act as binding material. It has property of setting and hardening when mixed with water to attain high strength. The properties of cement is depends upon chemical composition, the process of manufacture and degree of fineness of cement grains. Principal constituents of cement are lime, silica and alumina. In addition to this most of cement contains iron oxide, magnesia, sulphur trioxide and alkalies in small proportion. In this total project work Ordinary Portland Cement (OPC) of 53grade conforming IS 8112:2013 is used. Chemical composition of OPC is given in Table 4.1

Table 4.1:- Physical properties of cement

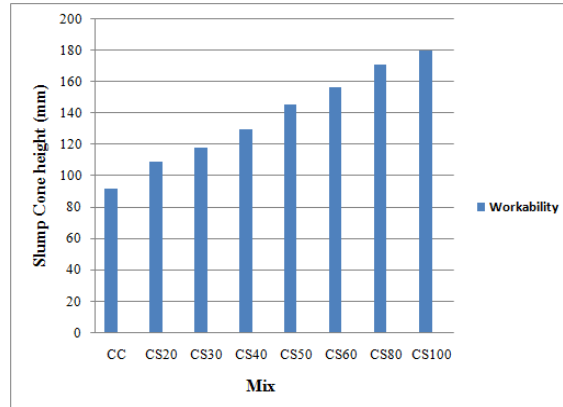
Sr No.	Cement	Initial setting time	Final setting time	Specific Gravity
1	OPC 53 Grade	30 min	620 min	3.15

4.2 Workability study

Workability of fresh concrete is checked immediately after mixing of water in dry concrete with the help of slump cone instrument. Slump test as per IS: 1199-1959 is followed [12]. Table 7 shows results of workability of various sets of concrete. The effect of copper slag replacement on workability of concrete is presented in graph 1.

Table 4.2: Workability of concrete mixture

Sr. No.	Mix Identity	Slump (mm)
1	CC	92
2	CS20	109
3	CS30	118
4	CS40	130
5	CS50	146
6	CS60	157
7	CS80	171
8	CS100	180



4.3 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. The final product is a solid, hard material that goes to the crusher for next processing. Copper slag is an irregular, black, glassy and granular in nature and its properties are similar to the river sand. Copper slag used in this work was brought from Sundara Enterprises (zone-II), a dealer in Bhosari MIDC area, Pune. The nature of copper slag used in experimental work shown in fig. 1. The physical and chemical properties of Copper slag are shown in table 3 and table 4.



Fig. 1 Copper slag

Table 4.3: Physical properties of copper slag.

Sr. No.	Physical Properties	Copper Slag
1	Particle shape	Irregular
2	Appearance	Black and glassy
3	Type	Air cooled
4	Specific gravity	3.74
5	Fineness modulus	2.89
6	Water absorption	0.40

V. OBSERVATION & RESULT DISCUSSION

5.1 Workability

Workability is a property of freshly mixed concrete, and a concrete is a mixture of cement, aggregate, water & admixture. Workability of fresh concrete is checked immediately after mixing of water in dry concrete with the help of slump cone instrument. Figure 4.3 shows the measurement of slump value obtained through workability test.

5.2 Compressive strength test

Out of many test applied to the concrete, compressive strength test is the almost important which gives an idea about all the characteristics of concrete. By this single test one can judge whether concreting has been prepared properly or not. Standard test procedure as per IS 516 (1959) is adopted to find compressive strength of all concrete mixes. The test setup used is shown in Figure 4.4 and the condition of specimens after testing is shown in Figure 4.5 respectively.

5.3 Flexural strength test

Flexural strength, also known as modulus of rupture, bend strength, or fracture strength. It is material property which is defined as the stress in a material just before it yields in a flexure test. It is measured in terms of stress, the procedure as per IS 516 (1959) is adopted to find flexural strength of concrete beam. Universal testing machine as shown in Figure 4.6 is used for this test and the condition of specimens after testing is shown in Figure 4.7 respectively.

5.4 UPV (Ultrasonic Pulse Velocity Test)

An ultrasonic pulse velocity test is an nondestructive test to check the quality of concrete. In this test, the strength and quality of concrete is assessed by measuring the velocity of an ultrasonic pulse passing through a concrete structure. This test is conducted by passing a pulse of ultrasonic wave through concrete to be tested and measuring the time taken by pulse to get through the structure. Higher velocities indicate good quality and continuity of the material, while slower velocities may indicate concrete with many cracks or voids. The quality of concrete was assessed using the guidelines given in table 2 of IS 13311 (PART 1)-1992 [14]. The Basic formula for estimating the pulse velocity is given by,

Pulse velocity = (Path length/Travel time)

Tables 12 show the ultrasonic pulse velocity for various replacement of copper slag in concrete. Graph 6 display effect of copper slag substitution as a fine aggregate on the ultrasonic pulse velocity of concrete.

REFERENCES

1. Al-Jabri K.S., Taha R.A., Al-Hashmi A. and Al-Harthy A.S. "Effect of copper slag and cement by-pass dust addition on mechanical properties of concrete", Construction and building materials, Vol. 20, pp. 322-331, 2006.
2. BipraGorai, 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.
3. Chavan R.R. and Kulkarni, D.B. "Performance of copper slag on strength properties as partial replacement of fine aggregate in concrete mix design", International Journal of Advanced Research and Studies, Vol.2, No.4, pp.95-98, 2013.
4. ThongamPrantic Singh, Dr.Rajashekhara.M.R. andSuhars R., "Utilization of Copper Slag as Fine Aggregates in Cement Concrete Pavements", International Journal for Research in Applied Science and Engineering Technology, Vol. 2 Issue VII, pp. 358-365, 2014.
5. Velumani and Maheswari, "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.
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. Madhavi,T.C. Effect of Copper Slag on the Mechanical Strengths of Concrete. International Journal of ChemTech Research, 8(12), 442 449, 2015.
8. Patil, M. V. Performance of Copper Slag as Sand Replacement in Concrete. International Journal of Applied Engineering Research, 11(6), 4349-4353, 2016
9. IS 12269 (1987) Indian Standard Ordinary Portland cement, 53 gradespecification. CED 2: Cement and Concrete.
10. IS 383 (1970) Indian Standard Specifications for Coarse and Fine aggregates from Natural Sources for Concrete. CED 2: Cement and Concrete.
11. IS 10262 (2009) Guidelines for Indian Standard Concrete Mix Design Proportioning. CED 2: Cement and Concrete.
12. IS 1199 (1959) Indian Standard Methods of sampling and analysis of concrete. CED 2: Cement and Concrete.
13. IS 516 (1959) Indian Standard Methods of tests for strength of concrete. CED 2: Cement and Concrete.
14. IS 13311-1 (1992) Indian Standard Methods Non-destructive testing of concrete: Part 1 Ultrasonic pulse velocity.