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Study on Strength and Durability of Concrete Using Copper Slag as a Partial Replacement of Fine Aggregate

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Abstract: In this experimental study is made on the compression strength, split tensile strength and flexural of concrete on partial replacement of fine aggregate by copper slag .Copper slag is the waste material from industry that generates approximately 2.5% tons of copper slag possesses the problem of disposal of waste and is of environmental concern. The demand for aggregates in concrete in construction industry is increasing rapidly and so is the demand for concrete. Thus it is becoming more important to seek suitable alternatives for aggregates in the future. This whole study includes that the replacement of fine aggregate by copper slag for different proportions of 0%,20%,30%,40%,50% and for a M40 grade of concrete will be used for a water cement ratio of 0.40.

Keywords: Cement, copper slag, compressive strength, split tensile strength, flexural strength.

I. INTRODUCTION

Concrete is a composite material composed of granular materials like coarse aggregate and fine aggregate as embedded in a matrix and bound together with cement as a binder which fills the space between the particles and glues them together. Concrete is the most preferred and the single largest building material used by the construction industry. Due to the over usage of sand in construction field there is a scarcity of sand. In order to fill the lacking of fine aggregate, copper slag can be used as a partial replacement of fine aggregate in concrete. Copper slag is an industrial by-product obtained during the matte smelting and refining of copper. The molten copper forms at the bottom of the furnace, while water or left in the air to cools. Sterlite Industries, Tamilnadu produces 0.4 million tons of copper every year. When one ton of copper is produced, 2.2 to 3 tons of copper slag is generated. Therefore, in Sterlite industries, 0.8 million tons of copper slag is generated every year (Brindha D. et. al., 2010). It is assumed that about 25 million tons of copper slag is generated in India every year[6]. Copper slag is glassy in nature and has a similar particle size range to sand, indicating that it could be used as a replacement for the sand. Since copper has high specific gravity so it is stable and durable. Fine powered copper slag can be used for the replacement of cement.

II. RELATED WORK

Alnuaimi (2012) studied the use of copper slag as a replacement of fine aggregate in RC slender columns. The percentage of fine aggregate was replaced from 0%, 20%, 40%, 60%, 80%, 100% using copper slag. Twenty columns of size 150 mm x150 mm x 2500 mm were tested under monotonic axial compression load until failure. Five cubes of size 100 mm x100 mm x100 mm, eight cylinders of size 150 mm x 300mm and five prisms of size 100 mm x 100 mm x 500 mm were cast and tested for each mixture to determine the compressive, tensile and flexural strengths of the concrete respectively. The results showed that the replacement up to 40% of fine aggregate with copper slag caused no major changes in concrete strength and further increasing the percentage reduced the concrete strength and column failure load and increased concrete slump, lateral deflections and vertical deflections of the column.

Ilangovan and Meenakshi Sudarvizhi (2011) reported in their paper, the highest compressive strength obtained was 46MPa for 100% replacement of fine aggregate by Copper Slag and Ferrous Slag and the corresponding strength for control mix was 30MPa. It has been observed that up to 80% replacement, copper slag and ferrous slag can be effectively used as replacement material for fine aggregate. The results showed that the compressive strength of copper slag and ferrous slag concrete increased when compared with control concrete (30.23MPa to 46.18MPa cured at 90 days), whereas the increased strength was more or less same for different percentage of copper slag &ferrous slag. The results showed that the split tensile strength of copper slag and ferrous slag concrete increased when compared with control concrete (6.10 MPa to 8.65 MPa cured at 90 days), whereas the strength increased was

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more or less same in different percentage of copper slag and ferrous slag in concrete.

III. Materials And Properties

Ordinary Portland cement from Chettinad Cement Company of grade 53 was used for this study which has the fineness 3%, Specific gravity 3.15, Consistency 30%, Initial setting time 36min and Final setting time 270 min. The physical properties of materials are tabulated in table1.

Table 1 Physical properties of materials

Material	Fine aggregate	Coarse aggregate	Copper slag
Specific gravity	2.6	2.85	3.718
Water absorption (%)	0.9	0.4	0.4%
Bulk density (kg/m^3)	1589.30	1452	1988.5 kg/m^3
Moisture content (%)	2.5	0.26	0.16%
Fineness modulus	3.10	3.06	4.42

IV. Methodology

The basic tests are conducted on various materials like OPC53 grade cement, fine aggregate, coarse aggregate and copper slag to check their suitability for making concrete. The mix proportions of concrete are modified for using copper slag as a partial replacement of fne aggregate. The cubes were cast by replacing fine aggregate with 0%, 20%, 30%, 40% and 50% of copper slag. Specimens are cast as per mix design and the tests are conducted after proper curing, the tests are compressive strength of cubes (150mm x 150mm x 150mm), split tensile strength of cylinders (150mm x 300mm) and flexural strength of prisms (100mm x 100mm x 500mm). From the studies, optimum results are found out and compared with the control concrete.

V. Mix Proportion

Based on the simplified mix design procedure as per IS 10262:2009, a concrete mix proportions with characteristic compressive strength of 40Mpa was designed and the mix adopted for the study is given in Table 2.

Table 2 Mix proportion

	Cement	Water	Fine Aggregate	Coarse Aggregate
kg/m^3	493	197.2	639.038	1198.197
Ratio	1	0.4	1.296	2.430

VI. Test Results And Discussion

The test results of slump, compressive strength, split tensile strength and flexural strength obtained from the experimental study are given in the form of graph and made discussion also.

A. Slump test

Slump test is conducted on fresh concrete of different mix proportions. The obtained slump value for normal concrete is 50 mm. This indicates medium workability.

Fig.1 shows the variation of slump value of concrete using copper slag. From the graph it is observed that in concrete, percentage of copper slag increases, it increases the workability.

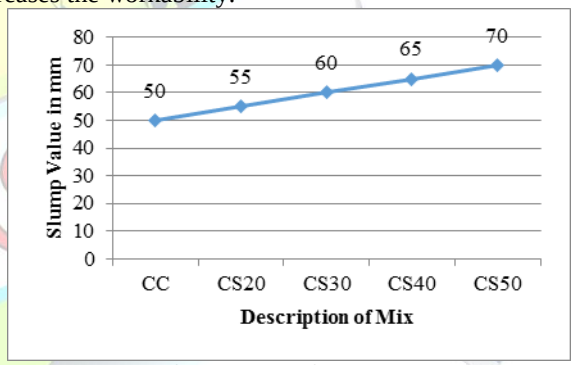

Fig.1 Variation of slump value of concrete using copper slag

B. Compressive strength

Concrete cubes of size 150 mm X 150 mm X 150 mm were prepared and the specimen is cured, it is tested for compressive strength. The maximum load at failure reading was taken.

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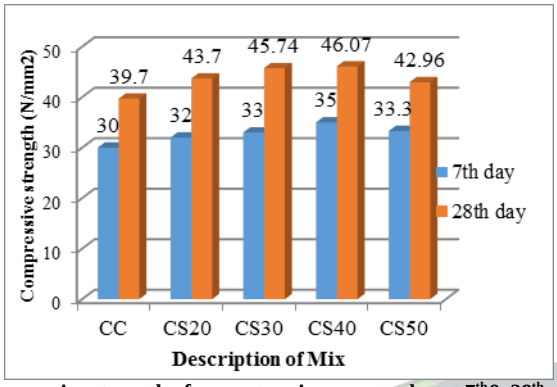

Fig.2 Compressive strength of concrete using copper slag at 7th& 28th day

Fig.2 shows the compressive strength of concrete using copper slag at 7th and 28th day. The results showed that the compressive strength of concrete is increased as copper slag quantity increases in concrete up to 40%, beyond that compressive strength was decreases due to increases free water content in the mixes. The excessive free water content in the mixes with copper slag content causes the bleeding and segregation in concrete. Therefore, it leads reduction in the concrete strength. The highest compressive strength was achieved at 40% replacement of fine aggregate with copper slag, which was found about 46.07 N/mm2 which is more than 30% compared to the control mix.

C. Split tensile strength

Concrete cylinders of diameter 150 mm and height 300mm were casted and the specimen is cured, it is tested for split tensile on 28th day. The maximum load at failure reading was taken.

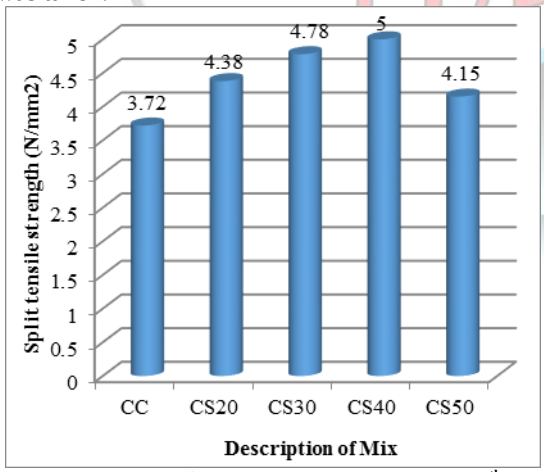

Fig.3 Split tensile strength of concrete using copper slag at 28th day

Fig.3 shows the split tensile strength of concrete using copper slag at 28th day. The split tensile strength of concrete showed similar behavior to the compressive strength. The results showed that the split tensile strength is increased upto 40% replacement of fine aggregate using copper slag, beyond that the split tensile strength value reduced but it more than the split tensile strength of control mix. The results showed that the replacement of fine aggregate using copper slag in concrete increases the tensile strength of about 25.60 % with that of control mixture.

D. Flexural strength

The flexural strength test for beam specimen having the size of100 x 100 x 500 mm was casted and cured at 28 days. It was kept horizontally between the loading surfaces of a universal testing machine and the load was applied until failure of the beam. The failure load was noted and shorter length from crack to support strength was measured.

Fig.4 shows the flexural strength of concrete using copper slag at 28th day. From the results, it is observed that optimum strength is obtained at 40 % replacement of sand with copper slag. The increased in strength is about 21.90%.

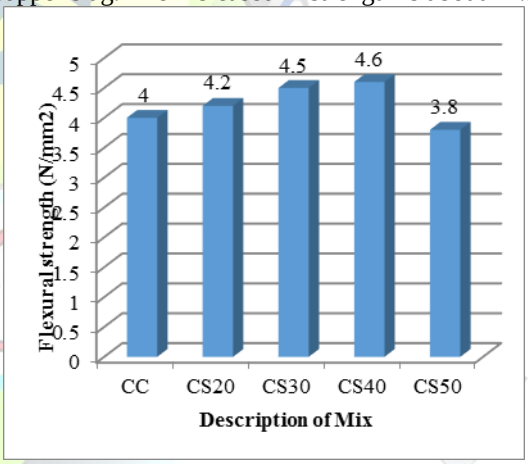

Fig.4 Flexural strength of concrete using copper slag at 28th day

VII. Durability Test Results

A. Sulphate attack test

The 150mm of cubes were immersed in the 5% of $MgSO_4$ solution for 28 days and found that the percentage loss in weight and compressive strength of concrete cubes. The result of the test showed that concrete containing copper slag has good resistance to sulphate attack. The loss in weight and compressive strength of concrete with 40% of copper slag was lower than control concrete. The percentage of loss of compressive strength of conventional concrete is 0.58% and percentage of loss in weight by 2.9% when compared with the concrete containing copper slag. The

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concrete cube containing copper slag resist the sulphate attack when compared to the control concrete. Table 3 shows the percentage of weight loss and strength loss in sulphate resistance test.

Table 3 Percentage of loss in weight and compressive strength due to Sulphate attack

Specimen	Loss in weight (%)	Loss in compressive strength (%)
Conventional cube	5.56	4.78
Cube contain 40% of copper Slag	3.24	2.78

B. Acid Resistance test

The acid resistance test was conducted in 150mm cubes by immersing in 5 % of Hydrochloric acid solution for 28 days. Then the weight loss and compressive strength were determined for the cubes. From the result, it was observed that the concrete having copper slag has good acid resistance when compared with control concrete. It could be in concrete, the use of copper slag prevents a growth of calcium hydroxide around the fine aggregate particles and prevents the formation of ettringite (sulfate calcium sulfoaluminate). Therefore, these mechanisms improve the concrete as resistance of concrete to acid attack. The obtained weight loss of control concrete is 3.44% and higher than the concrete with copper slag. The percentage of loss of compressive strength of control concrete is 1.98% and higher than the concrete containing copper slag. The concrete cube containing steel slag resist the acid attack when compared to the control concrete. Table 4 shows the percentage of weight loss and strength loss in acid resistance test.

Table 4 Percentage of loss in weight and compressive strength due to Acid attack

Specimen	Loss in weight (%)	Loss in compressive strength (%)
Conventional cube	7.32	10.7
Cube contain 40% of copper Slag	5.56	7.89

VIII. Conclusion

From the experimental works carried out, the following conclusions are made.

- Increasing the percentage of copper slag in concrete upto 40% increases the workability of concrete.
- The compressive, split tensile and flexural strength of concrete is increased with increasing of the percentage of copper slag upto 40%.
- The increase in percentage of copper slag in concrete shows higher resistance to acid and sulphate attack.
- From all the observation, it can be concluded that the slag added concrete give high strength and saves the material cost upto 10%.

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