Effect of Copper Slag when Partially Replaced with Fine Aggregate in Concrete

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Abstract— An experimental investigation was conducted to study the effect of using copper slag as a fine aggregate and the effect fly ash as partial replacement of cement on the properties high performance concrete. Totally eight concrete mixtures were prepared. Four mixes containing different proportions of copper slag ranging from 0% (for the control mix) to 65%. Four mixes containing fly ash as partial replacement of cement ranging at 25% constant. Concrete mixes were tested for compressive strength, split tensile strength and flexural strength. The results indicate that there is a increase in the strength about 40% with the increase of copper slag content, whereas the workability increased with increase in copper slag percentage. Addition of up to 45% of copper slag as sand replacement yielded comparable strength with that of the control mix. However, further additions of copper slag caused reduction in the strength due to an increase of the free water content in the mix. Mix with 65% copper slag replacement there is decreased in strengths. For this concrete containing 45% copper slag, fly ash is introduced in the concrete for better strength. Introduction of fly ash gave better results than concrete containing 45% copper slag. Workability got increased with further increase in fly ash content. Therefore, it is recommended that approximately 40% of copper slag can be used as replacement of sand and 25% fly ash can be used as replacement of cement in order to obtain high performance concrete.

Keywords: Cement Replacement, Copper Slag, High Performance Concrete, Sustainable

I. INTRODUCTION

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, 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. Copper slag is an industrial by-product material produced from the process of manufacturing copper. For every ton of copper production, about 2.2 tonnes 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 2003). Although copper slag is widely used in the sand blasting 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.

A. Aim:

To study the variation in characteristic behavior of concrete when silica fume and natural fibre (sisal) are introduced in concrete of grade M40 & M50.

B. Objectives:

In this research work, an extensive study using copper slag has been carried out to investigate the following.

1) To find the optimum proportion of Copper Slag that can be used as a replacement/ substitute material for fine aggregate in concrete
2) To find the optimum proportion of Fly Ash that can be used as a replacement/ substitute material for cement in concrete.
3) To evaluate compressive and tensile strength of copper slag and fly ash replaced concrete specimens.

C. Scope:

1) This study focuses on the strength performance of concrete with Copper slag and fly ash.
2) Strength is the most important property of concrete since the first consideration in structural design is that the structural elements must be capable of carrying the imposed loads.
3) Strength characteristic is also important because it is related to several other important properties which are more difficult to measure directly.

II. METHODOLOGY

In this experimental project concept of using copper slag in concrete was conceived. The addition of copper slag was conceived earlier to enhance the properties of concrete but the combination of fly ash and copper slag introduced simultaneously is being executed in this project. The knowledge on copper slag was also obtained by referring various journals. Review of literature was done and the concept was finalized various tests on Cement, fine aggregate and coarse aggregates were carried out to determine the material properties and prepare the mix design accordingly. In order to do find the merit or demerit of any special concrete, it has to be compared with conventional concrete. Therefore, a set of conventional concrete specimen is also required. In order to cast a set of conventional concrete, initially the mix design for M40 grade and M50 of concrete was made. Tests on fresh concrete were carried out. Workability was checked by carrying out slump test. The water cement was also determined based on three different designs of trail mix. The mix with optimum results were considered for casting conventional concrete.

The same mix ratio which was used to cast conventional concrete specimen, was also used to cast special concrete specimens which included addition of copper slag and fly ash. Special concrete specimens consist of cubes, cylinders and beams. OPC grade 53 cement was used in casting. The coarse aggregate added to the mix was divided into two portions. 60% of 20mm aggregate and 40% of 10mm aggregate was used. 8 mixes of special concrete specimens were casted and cured. Testing were carried out to find the compressive strength, split tensile strength and flexural strength for the special concrete at the age of 7 days and 28 days respectively. With the results obtained, the optimum percentage of copper slag and fly ash to be added is found out. With the results, the percentage which gives us the optimum result is found.

Following proportions were used in the concrete mix samples:

A. For M40: Table 1

Concrete Mixes	Copper Slag (CS)	Fly Ash (FA)
M40	0%	25%
M40	30%	25%
M40	45%	25%
M40	65%	25%

B. For M50: Table 2

Concrete Mixes	Copper Slag (CS)	Fly Ash (FA)
M50	0%	25%
M50	30%	25%
M50	45%	25%
M50	65%	25%

Table 1 & 2: The dry mixes composition of blended cement (wt.%)

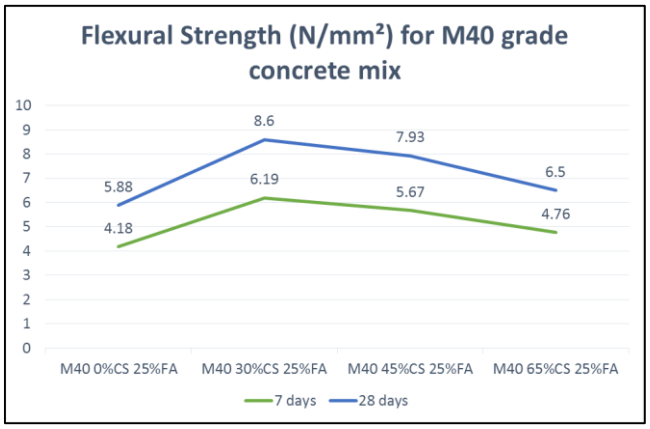
III. RESULTS AND DISCUSSIONS

A. Compressive Strength:

The test was conducted as per IS 516-1959 codal provision. The tests were carried out at a uniform stress after the specimen has been centered in the testing machine. For all mixes compressive strengths were determined at 7 days & 28 days. Compressive strength results which are obtained in M40 and M50 grades of concrete is represented as below:

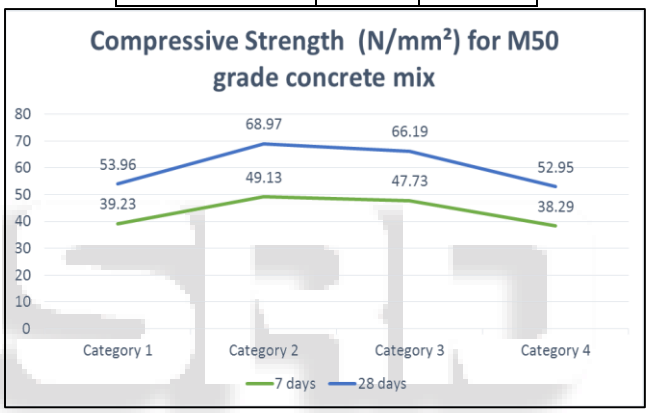
1) For M40:

Compressive Strength		
Mix	7 Days	28 Days
0%CS 25%FA	32.59	44.95
30%CS 25%FA	33.44	47.10
45%CS25%FA	36.58	50.11
65%CS 25%FA	30.16	41.30



2) For M50:

Compressive Strength		
Mix	7 Days	28 Days
0%CS 25%FA	39.23	53.96
30%CS 25%FA	49.13	68.97
45%CS 25%FA	47.73	66.19
65%CS 25%FA	38.29	52.95

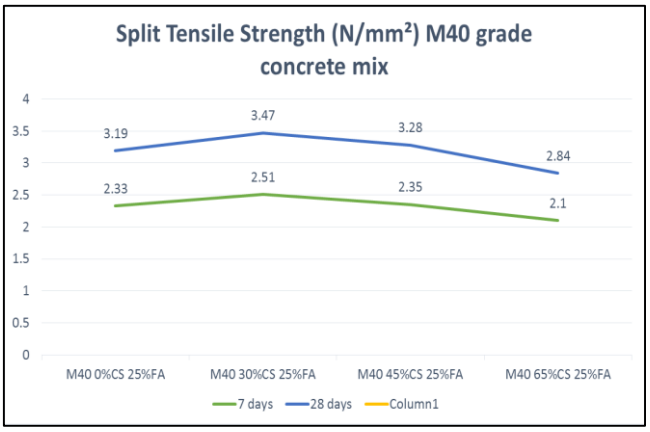


B. Split Tensile Strength:

The test was conducted as per IS: 5816-1999 codal provisions. For split tensile strength, the cylinder of 150mm diameter and 300mm height were used. In replacement of copper slag, the splitting tensile strength of concrete showed to be higher than that of the control concrete. This is due to the very fine particle of copper slag and its reaction with concrete. The split tensile strength which are obtained in M40 and M50 grades of concrete is represented as below:

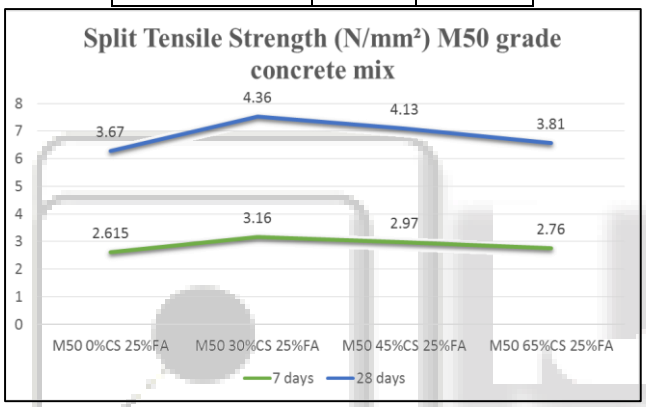
1) For M40:

Split Tensile Strength		
Mix	7 Days	28 Days
0%CS 25%FA	2.33	3.19
30%CS 25%FA	2.51	3.47
45%CS 25%FA	2.35	3.28
65%CS 25%FA	2.1	2.84



2) For M50:

Split Tensile Strength		
Mix	7 Days	28 Days
0%CS 25%FA	2.61	3.81
30%CS 25%FA	3.16	4.36
45%CS 25%FA	2.97	4.13
65%CS 25%FA	2.76	3.81

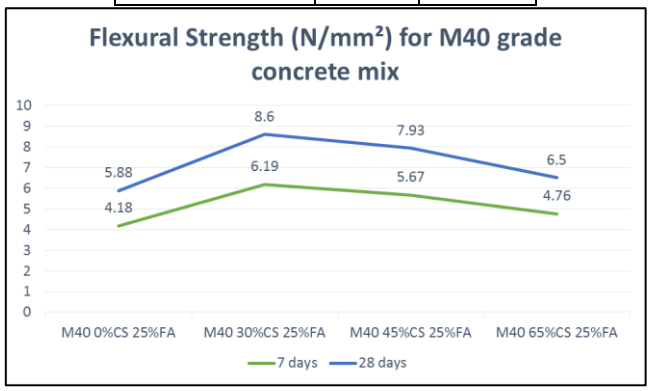


C. Flexural Strength:

The test was conducted as per IS: 516-1959 codal provisions. Flexure strength was measured by loading 150mm x150 mm x 700 mm concrete beams with a span at least three times the depth. The flexural strength which are obtained in M40 and M50 grades of concrete is represented as below:

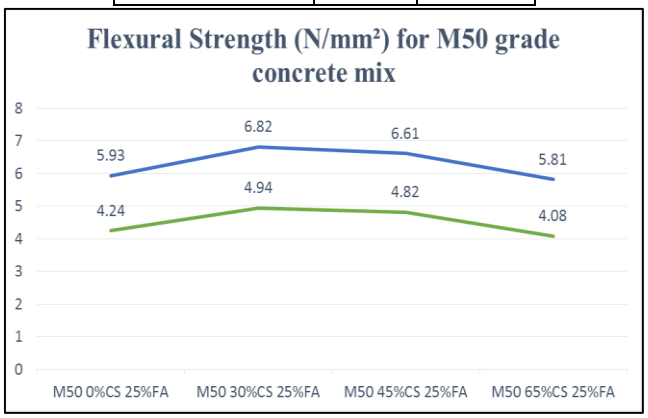
1) For M40:

Flexural Strength		
Mix	7 Days	28 Days
0%CS 25%FA	4.18	5.88
30%CS 25%FA	6.19	8.60
45%CS 25%FA	5.67	7.93
65%CS 25%FA	4.76	6.50



2) For M50:

Flexural Strength		
Mix	7 Days	28 Days
0%CS 25%FA	4.24	5.93
30%CS 25%FA	4.94	6.82
45%CS 25%FA	4.82	6.61
65%CS 25%FA	4.08	5.81



IV. CONCLUSION

From the above investigational work and test results, the following conclusions were arrived:

- The optimum percentage of copper slag and fly ash for maximum compressive strength was found to be 45% for M40 concrete mix.
- However for M50 grade concrete mix the optimum percentage of copper slag was 30% for compressive strength.
- The optimum percentage for split tensile strength was found to be 30% of copper slag for both M40 and M50 grade of concrete.
- With respect to flexural strength 30% copper slag addition gave optimum results for M40 and M50 grade.
- Workability increases with increase in percentage of copper slag.
- It is concluded that upto 30% to 40% replacement of copper slag induces higher strength properties and good workability properties.
- The strength of copper slag added concrete is higher when compared to conventional concrete.

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