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Experimental Investigation on Partial Replacement of Silica Fume and Copper Slag in Concrete

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Abstract

Concrete is the ideal material to produce the different shaped solid structures to carry the load. Concrete is a material composed of cement, fine aggregate, coarse aggregate and water. Since, concrete is the second largest material consumed the world, hence there continuous depletion in natural resources and some environmental problems. Large scale cement production leads to emission of large quantity Co_2 in atmosphere. And river sand is mostly used as a fine aggregate in concrete, because of that continuous depletion in river sand and also it affect the ground water table. Because of these reasons, there is need to search for alternate materials for concrete. Silica fume is used as a partial replacement for cement by 0%, 10% and 20% in concrete. Copper slag is used as a partial replacement for fine aggregate by 0%, 10%, 20%, 30%, 40% and 50%. Compressive strength, split tensile strength and flexural strength are strength parameters studied in this paper experimentally for various combinations of silica fume and copper slag content in concrete.

Keywords: Silica Fume, Copper Slag, Compressive Strength, Split Tensile Strength and Flexural strength.

I. INTRODUCTION

Cement is the most important ingredient of concrete and relatively high cost material and usage of river sand as fine aggregate in concrete leads to depletion of natural resource available from the river bed. Due to the requirement of huge quantity of concrete for infrastructure development all around the world, we need to search for some alternative for the material by using some of the available industrial byproducts as replacement. Concrete is composite material containing cement, water, coarse aggregate and fine aggregate. The resulting mixture of the material is casted to form required shapes and size for building a structure with capacity to carry the load exerted on it. Normally, silica fume is used to produce High Strength Concrete and copper slag is used to produce High Density Concrete. In this project, strength parameters compressive strength, split tensile strength and flexural strength of concrete for various proportion of silica fume and copper slag is determined. Cubes, cylinder and prisms were casted to determine the strength. Reinforced Concrete Beams are casted to study the load deflection effect for optimum content of silica fume and copper slag in concrete.

II. LITERATURE REVIEW

Amudhavalli and Mathew (2012), this work studied the effect of silica fume on strength and durability parameters of concrete. In this paper, concrete is produced by mixing silica fume and examined the output with respect to strength and durability properties of concrete. The main parameter investigated in this study is M35 grade concrete with partial replacement of cement by silica fume of 0, 5, 10, 15 and 20%. This paper presents a detailed experimental study on characteristics of concrete like compressive strength, split tensile strength, flexural strength at age of 7 days and 28 days. From the output it indicates that the use of silica fume in concrete has improved the performance of concrete in strength as well as in durability aspect. Tamilvanan and Sasikumar (2016), this work focused on the experimental investigation on properties of silica fumes as a partial replacement of cement. This paper investigated the properties of concrete with silica fume as an alternative material for cement. The main parameter investigated in this study is M30 grade concrete with partial replacement of cement by silica fume 0%, 25%, 30%, 40% and 50%. The experimental study on compressive strength and split tensile strength at age of 7 and 28days were conducted. Test results indicate that use of silica fume in concrete has improved the performance of concrete in strength at a particular percentage replacement. Although the highest compressive strength of concrete observed was 25% silica fume mix for ordinary Portland cement and the result gradually decreases when increase in replacement ratio. Madhavi et al. (2015), this work focused on effect of copper slag on the mechanical strengths of concrete. Experimental investigations are carried out by replacing the sand with copper slag in proportions of 10%, 20%, 30%, 40%, 50%, 60% and 100% keeping all other ingredients constant. It was seen that the optimum content of copper slag is 40% beyond which the strength starts decreasing. Patil et al. (2016), this work investigates the effect of copper slag as sand replacement in concrete. This paper presents the experimental results of concrete with partial replacement sand by copper slag to determine the optimum percentage of copper slag to be used in concrete to attain good strength. The effect of replacing fine aggregate with copper slag on the Workability, Compressive Strength, Split Tensile Strength, Flexural Strength, Density, Modulus of Elasticity and Permeability of concrete are studied in this work. This paper gives the conclusion that addition of copper slag up to 40% is effective to increase the compressive strength and impermeability of concrete.

III. MATERIAL PROPERTIES

OPC 53 Grade Cement was used. Cement is a binding material used in the preparation of concrete. It binds the coarse aggregate and fine aggregate with help of water, to form a monolithic material and also it fills the fine voids in the concrete. Properties of cement used in this experiment is given in the below Table 1.

Table 1. Properties of Cement

Parameters	Values
Specific gravity	3.15
Initial setting time (min)	48 min
Final setting time (min)	210 min
Bulk Density (Kg/m^3)	4%

Fig.1 Cement

River Sand is used as fine aggregate. Sand is a naturally occurring granular material composed of different particle size. Based on the fineness of sand, sand is classified as different zone. In this project sand of zone-III is used for entire work. Aggregate passing through the 4.75mm IS-Sieve is commonly used fine aggregate for concrete production. Properties of sand used in this experiment is given in the below Table 2.

Table 2. Properties of Fine Aggregate

Parameters	Values
Specific Gravity	2.65
Fineness Modulus	2.77
Bulking (%)	9
Water absorption (%)	1.12
Bulk Density (Kg/m^3)	1530

Fig.2 Fine Aggregate

Coarse Aggregate which is retained on 4.75mm IS-Sieve is to be used as a coarse aggregate in concrete. Coarse aggregate used is locally available crushed angular aggregate of size 20mm for this experimental work. The properties of coarse aggregate used in this experiment is given in the below Table 3.

Table 3. Properties of Coarse Aggregate

Parameters	Values
Specific gravity	2.68
Water absorption (%)	0.98
Impact value (%)	34.67
Bulk Density (Kg/m^3)	1680

Fig.3 Cement

Silica Fume is a byproduct obtained from production of silicon metal or ferrosilicon alloys. Because of its highly reactive pozzoloanic behavior, it is used in high performance concrete. Concrete containing silica fume can have very high strength and can be very durable. The properties of Silica fume is given in the Table 4.

Table 4. Properties of Silica Fume

Parameters	Values
Specific gravity	2.63
Density (gm/cc)	0.76
Moisture (%)	0.06
Silica as SiO_2 (%)	99.89
Alumina as Al_2O_3 (%)	0.04

Fig.4 Silica Fume

Copper Slag is a byproduct of copper extraction by smelting. During smelting, impurities become slag which floats on the molten metal. Slag that is quenched in water produces angular granules which are disposed as waste. It can be used as a replacement for fine aggregate in concrete and it also improves the strength of concrete up to certain percentage of replacement. The properties of copper slag used in this experiment mentioned in the Table 5.

Table 5. Properties of Copper Slag

Parameters	Values
Specific Gravity	4.9 to 5.3
Density (gm/cc)	4 to 4.5
Ferric Oxide as Fe_2O_3 (%)	>90

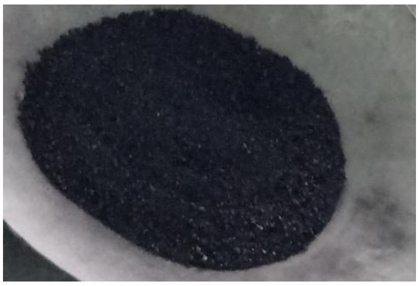


Fig.5 Copper Slag

IV. CASTING OF SPECIMENS

Specimens for various combinations of silica fume and copper slag in concrete were casted and tested to determine different strength parameters. The total number of specimen casted is mentioned in the Table 3.7. Cube of size 150mm × 150 mm × 150mm were casted to determine the Compression Strength of concrete. Cylinder of size 150mm diameter and 300mm height were casted for Split Tensile Strength Test. Prismatic Beam of size 100 mm × 100 mm × 500mm were casted for Flexural Strength Test. Reinforced concrete beams of size 100mm × 200mm × 1200mm were casted to study the load-deflection behavior of beam, where only for optimum mix beams were casted. The optimum mix is obtained from the compressive strength, split tensile strength and flexural strength test results. Specimen batching and casting methods were described in the Fig.6 & Fig.7.

Table 6. Mix Proportions

Mix	Binder		Fine Aggregate		Coarse Aggregate (%)
	Cement (%)	Silica Fume (%)	River Sand (%)	Copper Slag (%)	
M1	100	0	100	0	100
M2	100	0	90	10	100
M3	100	0	80	20	100
M4	100	0	70	30	100
M5	100	0	60	40	100
M6	100	0	50	50	100
M7	90	10	100	0	100
M8	90	10	90	10	100
M9	90	10	80	20	100
M10	90	10	70	30	100
M11	90	10	60	40	100
M12	90	10	50	50	100
M13	80	20	100	0	100
M14	80	20	90	10	100
M15	80	20	80	20	100
M16	80	20	70	30	100
M17	80	20	60	40	100
M18	80	20	50	50	100

Fig.6. Batching of Materials

Fig.7a. Cube Casted

Fig.7b. Casted Cylinder

Fig.7c. Casted Prism

V. TESTING OF SPECIMENS

Compressive Strength of concrete cube at the age of 7 and 28 days of curing were tested using compression testing machine of capacity 2000 kN. Once the specimen is fixed as shown in the experimental setup the load is applied gradually to the cube and the ultimate load at the failure of the cube is noted and the compressive strength of the cube is calculated. The test specimen is shown in the Fig.8.

Fig.8 Compression Strength Testing

Split Tensile Test of cylindrical specimens of size 150mm diameter and 300mm height were tested for 28days of curing. These tests were carried using compression testing machine of capacity 2000 kN. The test specimen is shown in the Fig.9.

Fig.9 Split Tensile Strength Testing

Flexural Strength Test evaluates the tensile strength of concrete indirectly. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending. The results of flexural test on concrete expressed as a modulus of rupture which denotes as MPa. The beam specimens of size 100 mm × 100 mm × 500mm were used. Specimens were dried in open air after 7 and 28days of curing and subjected to flexural strength test under flexural testing assembly shown in Fig.10.

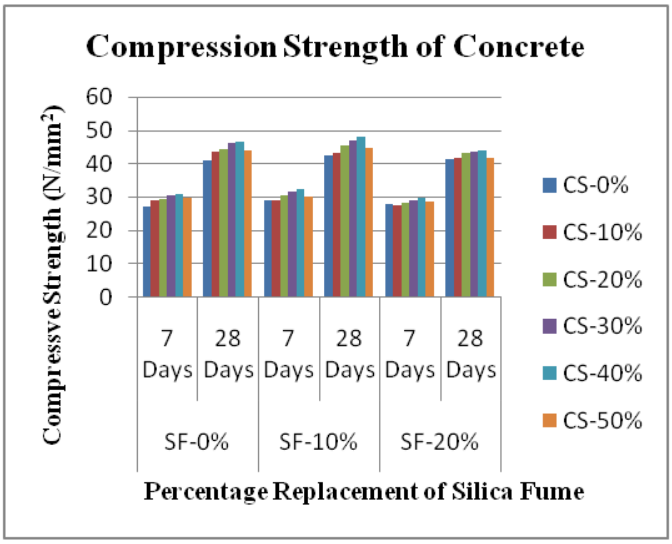
Fig.10 Flexural Strength Testing

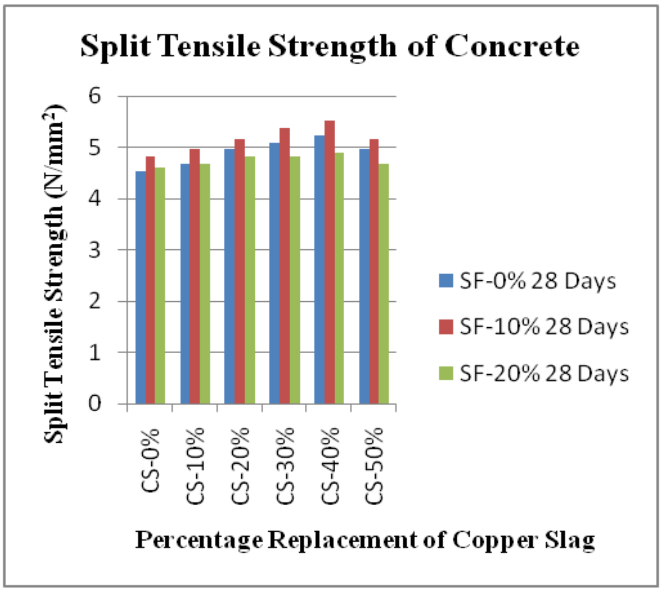
VI. RESULTS AND DISCUSSION

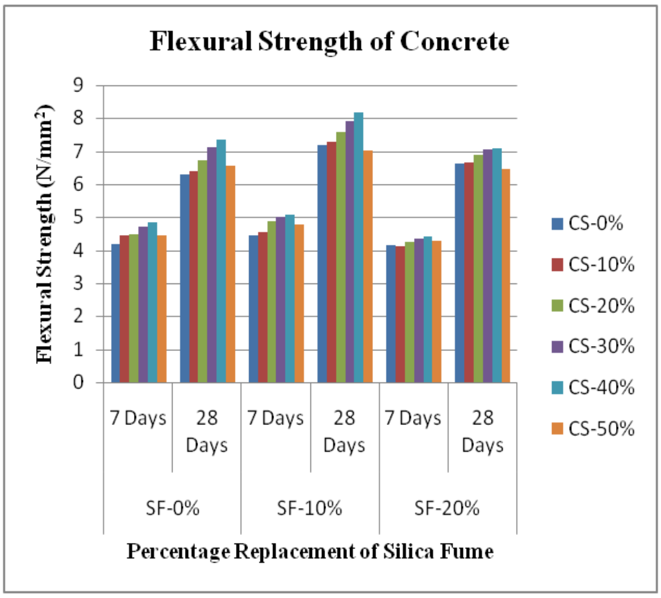
In this experimental study specimens are casted for various mix and tested to determine the strength parameters like compressive strength, split tensile strength and flexural strength and concrete. Those test results were discussed below Table 7 and Flow Charts.

Table 7. Test Results

Mix	Compressive Strength		Split Tensile Strength	Flexural Strength	
	7 Days	28 Days	7 Days	7 Days	28 Days
M1	27.11	40.89	4.529	4.176	6.288
M2	28.89	43.56	4.671	4.448	6.384
M3	29.33	44.44	4.954	4.496	6.72
M4	30.67	46.22	5.096	4.704	7.136
M5	31.11	46.67	5.237	4.848	7.344
M6	29.77	44	4.954	4.464	6.56
M7	28.89	42.67	4.812	4.464	7.184
M8	28.89	43.11	4.954	4.544	7.296
M9	30.67	45.33	5.166	4.88	7.568
M10	31.56	47.11	5.379	5.008	7.92
M11	32.44	48	5.52	5.088	8.176
M12	30.22	44.89	5.166	4.768	7.008
M13	28	41.33	4.6	4.16	6.624
M14	27.56	41.78	4.671	4.112	6.672
M15	28.44	43.11	4.812	4.256	6.88
M16	28.89	43.55	4.812	4.336	7.04
M17	29.78	44	4.883	4.416	7.088
M18	28.67	41.78	4.671	4.288	6.448







SF - Silica Fume

CS - Copper Slag

VII. CONCLUSION

Compressive strength, split tensile strength and flexural strength are the different strength parameters investigated experimentally in this project work for various proportions of silica fume and copper slag in concrete. The test result shows, 10% of silica fume and 40% of copper slag in concrete produces the better strength when compared with other combinations and normal concrete. Since, both the admixtures are obtained as byproduct from the industrial source. It helps to decrease the material cost without decrease in strength of concrete.

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