Utilization of Silica Fume And Copper Slag In Regular Concrete By Material Replacement Technique

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Abstract- *Concrete, a homogeneous mixture of cement, fine aggregate, coarse aggregate and water is widely been used in construction activities. But cement and fine aggregate are becoming consequently costlier and their demand also increases every day. There is a push towards sustainability in recent times in the construction industry. As large scale production of cement causes emission of greenhouse gases and depletion of natural resources and also natural sand of good quality are becoming scarcer and costlier due to non-accessibility of river during entire year, illegal dredging, rapid growth of construction activities etc. So it is necessary to search an alternative material to use as cement and natural sand in construction activities. The use of silica fume as a partial replacement of cement is an effective method of pollution reduction and conservation of resources, since it reduces cement use. In addition, silica fume is used in combination with copper slag to make concrete structures more durable. The present work is directed towards developing a better understanding on strengths characteristics of concrete using as a partial replacement of cement by silica fume and fine aggregate by copper slag. The Dissertation work is carried out with M20 grade concrete and tests were conducted. Concrete mixtures were evaluated for workability, compressive strength and split tensile strength.*

Keywords- Silica fume, Copper slag, workability, compressive strength, split tensile strength test, water absorption test.

I. INTRODUCTION

In the last decades, environmental sustainability has become one of the most important issues. Because of global growth and non-renewable resource scarcity resulting in severe environmental Issues (WCED, 1987; IPCC, 2007) Not only the reduction of Greenhouse Gas (GHG) emissions and of fossil energy utilization, but Also the efficient use of materials is the most important aspects that need to be taken into account in production chain analysis. Recently, the most material-consuming industries are considered by researchers, policy makers and environmental agencies in order to redesign production chains aiming to reduce their environmental impact. Clinker, cement, and concrete production represent a set of processes characterized by high CO2 emissions, huge energy consumption, and intensive utilization of natural resources (WBCSD, 2002; Italcementi Group, 2006).

On the other hand river Sand is a common kind of fine aggregate used in the fabrication of concrete. Alternative to river sand, which is a usual pattern of fine aggregate in preparation of concrete have been in demand due to large scale depletion of river bottom and increasing price of river sand. Many non-established resources such as Stone Dust, Carbonate Sand, Fly Ash, Copper Slag etc. with a larger percentage of Silica (SiO2) have been strained out as an alternative to river sand as fine aggregate in preparation of concrete

To reduce mainly the natural resource consumptions different production chains whose byproducts can substitute natural materials mixed with cement and/or concrete are investigated and, then, modeled. Hence, concrete and by-products production chains are jointly modeled to evaluate comprehensive and environmental benefits, the effective design of linked production chains, and to compare different economical and technical solutions. For instance, materials resulting from building demolition are proved to be effective also in terms of reduction of landfill space consumption.

II. REVIEW OF LITERATURE

A lot of work has been done to explore the benefits of using pozzolanic materials in making and enhancing the properties of concrete. Literature review of Silica fume and Copper Slag is presented in the following sections.

Leema Rose & Suganya Examined the Performance of Copper Slag on Strength and Durability Properties as Partial Replacement of Fine Aggregate in Concrete. The primary purpose of this work is to determine the strength and durability properties of concrete in which fine aggregate replaced with Copper slag partially by 10%, 20%, 30%, 40%. They reasoned out that the addition of copper slag in concrete increases the density of the concrete. The results of compressive tests show that the strength of the concrete increases with respect to the percentage of copper slag added by weight of fine aggregate up to 30% of replacement of copper slag strength was found to be 45.42 N/mm2 for a design mix 1: 1.4: 2.6 keeping w/c ratio as 0.4.

D. Patil, Patil & Veshmawala Observed the Performance of Copper Slag as Sand Replacement in Concrete.M30 concrete was used and several tests like compressive, flexural, split tensile strength were taken for different portions of copper slag and sand from 0 to 100%. The outcome showed that workability increases with growth in percentage of copper slag. Maximum Compressive strength of concrete increased by 34 % at 20% replacement of fine aggregate with copper slag, and up to 80% replacement of copper slag, concrete gain more force than normal concrete strength. The flexural strength of concrete found to be increased by 14% with 30% substitution of copper slag. [5]

Arivalagan conducted an Experimental Study on the Flexural Behavior of Reinforced Concrete Beams as Replacement of Copper Slag as Fine Aggregate. The test results of concrete were obtained by adding copper slag to sand in various percentages ranging from 0%, 20%. 40%, 60%, 80% and 100%. All specimens were cured for 28 days before the compression strength test, splitting tensile test and flexural strength. The high compressive strength obtained was 35.11MPa (for 40% replacement) and the corresponding strength to control mix was 30MPa.

Sasikumar & Tamilvanan Performed an Experimental Investigation on Properties of Silica Fumes as a Partial Replacement of Cement. The main parameters investigated in this study is M30 grade concrete with partial replacement of cement by silica fume0%, 25%, 30%, 40% and 50%. The normal consistency increases about 40% when the silica fume percentage increases from 0% to 25%. The optimum 7 and 28-day compressive strength has been obtained in the 25 % silica fume replacement level. As well the split tensile strength is high when using 25% silica fume replacement for cement.

Ghutke & Bhandari Examine the Influence of silica fume in concrete. Results indicated that the silica fume is a better replacement of cement. The rate of strength gain in silica fume concrete is high. Workability of concrete decreases as increase with % of silica fume. The optimum value of compressive strength can be achieved in 10% replacement of silica fume. As strength of 15% replacement of cement by silica fume is more than normal concrete. The optimum silica fume replacement percentage is varying from 10 % to 15 % replacement level.

III. MATERIALS AND METHODS

The experimental investigation work is started with various tests on the constituent materials. The constituent materials are given below.

1. Cement
2. Coarse aggregate
3. Water
4. Silica fume
5. Copper slag

1. Cement

Ordinary Portland cement of 43 grades manufactured by Shree Ultratech Cement was used throughout the Experimental investigation. The quality of the cement was confirming to IS 8112:1989 was used in the field.

2. Fine Aggregate

Fractions from 4.75 mm to 150 microns are termed as fine aggregate. Locally available river sand passed through 4.75mm IS sieve is applied as fine aggregate conforming to the requirements of IS 383:1970.

3. Coarse Aggregate

Coarse aggregate shall be of hard broken stone of granite shall be of hard stone, free from dust, dirt and other foreign matters. The stone ballast shall be of 20mm and down and should me retained in 5mm square mesh and well graded such that the voids do not exceed 42 percent. Aggregate most of which is retained on 4.75-mm IS Sieve and containing only so much finer material as is permitted for the various types described in this standard.

4. Silica Fume

Silica fume is the byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses of silica fume uses for concrete because of its physical and chemical properties. Concrete containing silica fume can have high strength and can be durable.

Sl.No	Description	Physical Properties
1	Specific Gravity	2.2
2	Mean Grain Size (Mm)	0.1
3	Colour	Light To Dark Grey

5. Copper slag

Copper slag is one of the materials that can be considered as a waste material which could have a promising future in construction industry as partial substitute of aggregates. Copper slag is a by-product 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 of as waste.

Table 3.1 shows the Physical Properties of copper slag

Sl.No	Description	Physical Properties
1	Specific Gravity	3.63
2	Chloride Content	<0.0002
3	Colour	Black colour

IV. MIX DESIGN

The property of workability, therefore, becomes of vital importance. The mix design is done as per IS 10262-2009. Percentage dosage of super plasticizer (high range water reducers) is an additional parameter to be considered for designing an OPC mix. Percentage dosage of super plasticizer was fixed as per the mix design method described in IS 10262-2009. Mix proportion was arrived through various trial mixes. The grade of concrete prepared for the experimental study was M20.

TABLE 4.1 shows the materials proportion

Water Cement Ratio (kg/m^3)	Cement (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)
197.16	394.32	685.45	1115.29

V. RESULTS AND DISCUSSIONS

The present study aims to investigate the compressive strength and basic properties such as moisture content and water absorption of composite made of cement, silica fume, fine aggregate, copper slag and coarse aggregate. Specimen are prepared in certain sizes and, cured for 28 days and tested at 14 and 28 days

The amount of cement and fine aggregate are partially replaced by silica fume and copper slag. The silica fume and copper slag is replaced based on the percentage of cement and fine aggregate content. The investigation is expected to have basic characteristics or basic properties of composite materials such as load carrying capacity and durability can be established. Also, the information may be very useful for future study and future development. So improvement to building materials can be carried out in more detail manner.

5.1 REPLACEMENT DETAILS

The replacement details of silica fume and copper slag has been given in the below table. The replacement of cement percentages by 10%, 20%, 30% with silica fume and after getting optimum percentage keeping optimum silica constant varying the fine aggregate replacement percentages by 10%, 20%, 30%, 40% and 50%. There will be no changes in the quantity of coarse aggregate.

5.2 Effect of Copper Slag with Micro Silica on workability

Workability is defined as the properties of freshly mixed concrete or mortar which determines the homogeneity with which it can be mixed, placed, consolidated and finished. In general terms, workability represents the amount of work which is to be done to compact the concrete in a given mould. A workable mix should not segregate. In this study workability was measured by conducting slump cone test.

The slump of the freshly mixed concrete was measured by using a slump cone in accordance to ASTM C143. It can be observed from Table 5.1 that all mixtures have a slump of less than 45mm and are observed that slump values increasing with increase in slag content.

TABLE 5.1 shows the slump values of different mix proportions

MATERIAL PROPORTION	SLUMP(mm)
0%SF + 0%CS	25
10% SF+ 10% CS	31
10% SF+ 10% CS	33
10% SF+ 20% CS	36
10% SF+ 30% CS	38
10% SF+ 40% CS	41
10% SF+ 50% CS	44

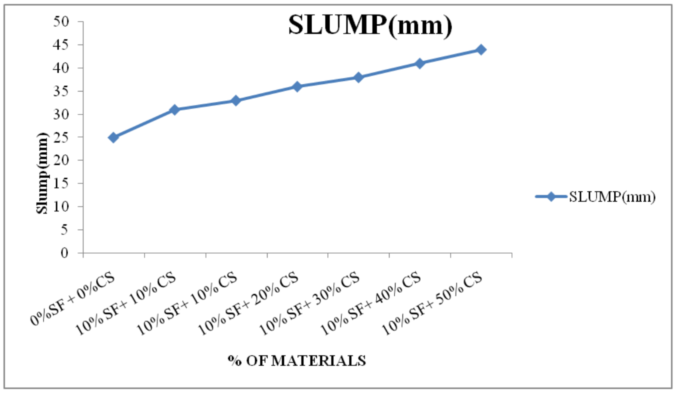

Fig 5.1 Slump values of different mixes of concrete with silica fume and copper slag

5.3 Effect of Silica fume on Compressive Strength

5.3.1 COMPRESSIVE STRENGTH

The main function of the concrete in structure is mainly to resist the compressive forces. When a plain concrete member is subjected to compression, the failure of the member takes place, in its vertical plane along the diagonal. The vertical cracks occur due to lateral tensile strain. A flow in the concrete, which is in the form of micro crack along the vertical axis of the member will take place on the application of axial compression load and propagate further due to the lateral tensile strain.

Cubes are prepared of size 150 mm x 150 mm x 150 mm are checked for compressive strength. The specimens tested for 7, 14 and 28 days. The specimen were tested for compressive strength parallel to the plane of the board by applying increasing compressive load until failure occur. The arrangement of load is applied to the specimen by placing the specimen length vertical between the surfaces of the testing machine. Prior to that, measurement for the thickness and width was carried out in order to get the values of cross section area for the test specimens.

Compressive strength of concrete mixed made with and without Silica fume of cube size 150mm x 150mm x 150mm was determined at 7,14 and 28 days. Here silica fume was added 10%, 20%, and 30% by weight of cement. It was observed that for 10% replacement the compressive strength was greater than controlled concrete. For increase in percentage of replacement the compressive strength was less than controlled concrete.

Table 5.2: shows that the compressive strength for 7, 14 days and 28 days curing strength.

% REPLACEMENT OF SILICA FUME	7 days	14 days	28 days
0	13.2	21.06	23.4
10	14.5	23.05	25.9
20	12.9	20.6	23.16
30	11.82	19.1	21.5

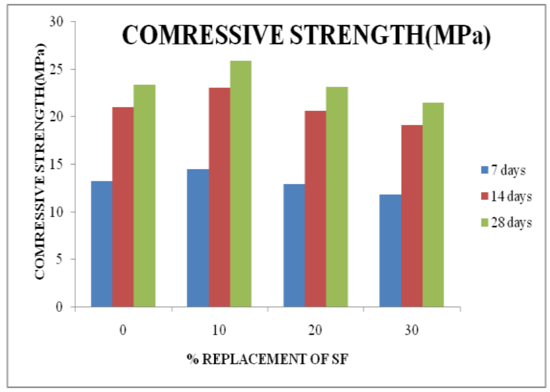

Fig 5.2 Compressive strength of concrete for different percentage replacement of silica fume

5.4 Effect of Copper Slag with Micro Silica on Compressive Strength

Test specimens of size 150 *150* 150 mm were prepared for testing the compressive strength concrete. The concrete mixes with 10% of silica fume as partial replacement of cement is kept constant and varying the proportions of sand by copper slag by 10% to 50% with an interval of 10% were cast into cubes and cylinders for subsequent testing. In this study, to make concrete, cement and fine aggregate were first mixed dry to uniform colour and then coarse aggregate was added and mixed with the mixture of cement and fine aggregates. Water was then added and the whole mass mixed. The interior surface of the moulds and the base plate were oiled before concrete was placed. After 24 hours the specimens were removed from the moulds and placed in clean fresh water at a temperature of 27^0 C. The specimens so cast were tested after 7, 14 and 28 days of curing measured from the time water is added to the dry mix.

Table 5.3: shows that the compressive strength for 7, 14 days and 28 days

PROPORTION	7 days	14 days	28 days
10% SF+ 0% CS	14.5	23.05	25.9
10% SF+ 10% CS	15.7	25.1	28.21
10% SF+ 20% CS	17.64	28.03	31.5
10% SF+ 30% CS	19.09	30.27	34.1
10% SF+ 40% CS	15.92	25.31	28.44
10% SF+ 50% CS	13.83	21.65	24.71

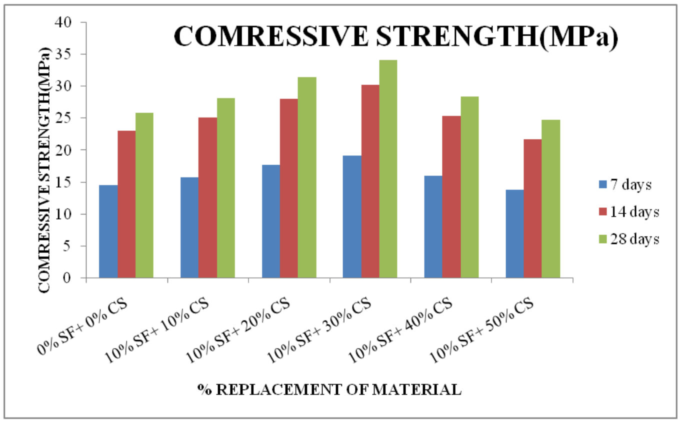

Fig 5.3 Compressive strength of different mixes of concrete with silica fume and copper slag

5.5 Effect of Copper Slag with Micro Silica on Split tensile strength

Test specimens of size 100* 200 mm were prepared for testing the split tensile strength of concrete. The concrete mixes with varying percentages (0%, 10%, 20%, 30%, 40% and 50%) of copper slag as partial replacement of sand by fixing 10% of cement is replaced by silica fume were cast into cylinders for subsequent testing.. The specimens so cast were tested after 7 and 28 days of curing measured from the time water is added to the dry mix. Results of the split tensile strength test on concrete with varying proportions of silica fume replacement at the age of 7 and 28 days are given in the Table 5.4. The cylinder strength results of concrete mix are also shown graphically in Figure 5.4. The tensile strength increases as compared to control mix as the percentage of copper slag is increased up to 30%.

As increase the percentage of copper slag its compressive strength increases continuously from 10% to 30% respectively and after 30% its start decreasing. Fig 5.4 shows the variation of percentage increase in tensile strength with replacement percentage of silica fume and copper slag. The results also indicate that early age strength gain i.e. at 7 and 28 days, is higher when compared to the control mix if 10% of cement is replaced by silica fume and 30% with copper slag.

Table 5.4: shows that the Split tensile strength for 7 and 28 days

MIX PROPORTION	7 days	28 days
0%SF + 0%CS	1.12	1.81
10% SF+ 0% CS	1.31	1.89
10% SF+ 10% CS	1.42	2.13
10% SF+ 20% CS	1.56	2.43
10% SF+ 30% CS	1.69	2.89
10% SF+ 40% CS	1.52	2.41
10% SF+ 50% CS	1.46	2.32

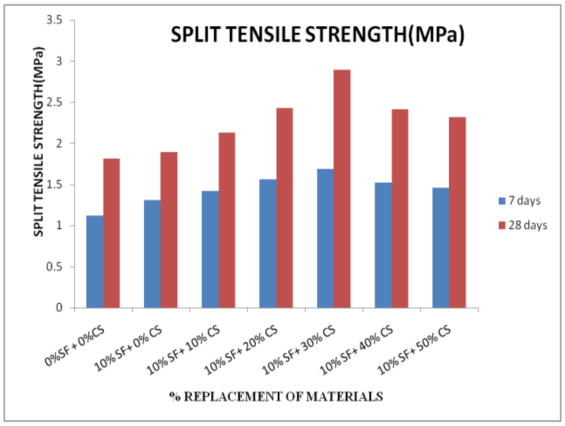

Fig 5.4 Split tensile strength of different mixes of concrete with silica fume and copper slag

VI. CONCLUSIONS

The Conclusions and Recommendations that could be drawn from the results of this project and experiments are summarized and the use of silica fume as a cement replacing material in cement and replacement of fine aggregate with copper slag in concrete production was studied and after the research work is done, the following conclusions were made:

- Silica fume in concrete performed better when compared to ordinary concrete up to 10% replacement of Silica fume.
- Increase of strength is mainly to presence of high amount of Silica in Silica fume.
- Compressive strength is increased for 7, 14 and 28 days when cured in normal water upto 10% replacement of cement with silica fume, and then decreased with increase in silica fume content.
- Keeping 10% silica fume as a cement replacement, fine aggregate is replaced with copper slag by 10% to 50%. For 10% silica fume and 30% copper slag compressive strength is more than the controlled mix and the increment in compressive strength is about 45.7%.
- The cylinder strength results of concrete mix are also observed and it shows that the tensile strength increases as compared to control mix as the percentage of copper slag is increased up to 30%.
- Finally the results of this research work have revealed that cement could advantageously be replaced with silica fume up to 10%. This replacement results in similar concrete properties to that of the control concrete. Higher replacement percentages can also be used with a slight reduction in the performance of the concrete.
- Utilization of the waste materials like silica fume and copper slag can be advantageously used as a replacement

of cement and fine aggregate respectively in the preparation of concrete.

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