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Evaluative study on blended concrete using copper slag and silica fume as a partially replacement material

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Abstract
As in today's Industrial waste is used to make cement and concrete in the constructional field. New by-products and waste material are produced in the industry. Damping or Disposal of these materials causes environmental as well as health problems There is a lot of potential in the concrete industry to recycle waste material. High performance concrete is technically and economically very helpful due to its used in massive volumes. This Study faces on the Strength performance of concrete with copper slag, silica fume and its blend. Cement & Sand replacement by various percentage with copper slag, silica fume and its blend are studied. Concrete tests are conducted on the concrete samples at the specific ages. The comparison made on the basis of compressive and tensile strength performance of copper slag and silica fume. Respective figures and discussion will be made to find out the optimum result and make it more sustainable product to be used for the construction.

Keywords: copper slag, silica fume, blended concrete, compressive strength, split tensile strength, flexural strength

1. Introduction

Concrete is the most widely used construction material in all over the world. Aggregates are the most important component of concrete and about 42 % of 15 billion tons of aggregates Produced each year are used in concrete, of which only 8 % are recycled aggregates. There is a lot of potential in the concrete industry to recycle waste material. For many years, by-products such as fly ash, silica fume and slag were considered as waste materials. Due to this the concrete improved it's workability and durability compared to normal concrete and has been used in the construction of power, chemical plants and under-water structures. The waste material such as copper slag which can used as partial or full substitute of either cement or aggregates. It is a by- product obtained during the matte smelting and refining of copper approximately 2.2–3.0 tons copper slag is generated as a by-product material to produce every ton of copper. This slag is currently being used for many applications like land filling, grit blasting, etc. and utilizes only about 15–20 % of the copper slag generated. Silica fume is used as an admixture or Replacement of cement and other concrete constituents. It is an ultrafine powder collected as a by-product of silicon and ferrosilicon alloy production which can be readily used as a replacement for cement thus reducing the effect of Portland cement. The researches shows that the silica fume have a beneficial influence on strength and durability of reinforced concrete. When pozzolanic materials are incorporated to concrete, the silica present in these materials reacts with thecalcium hydroxide released during the hydration of cement and forms additional calcium silicate hydrate (C-S-H), which improve the mechanical properties of concrete.

2. 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 Silica Fume that can be used as a replacement/ substitute material for cement in concrete.
3. To evaluate mechanical properties by use of copper slag and Silica Fume in concrete specimens.

3. Literature Review

A. Katz *et al*. [1] says The role of silica-fume agglomerates, found in densified silica-fume (DSF) pastes, in the immobilization mechanism of Cs ions was studied. this work suggests that during the pozzolanic reaction, a hydrated rim develops around the agglomerate that acts as an additional diffusion barrier for the Cs ions, resulting in an increased efficiency of Cs immobilization.

Rizwan *et al*. [2] says The current research is aimed to investigate the sustainable utilisation of CS as fine aggregates in Self Compacting Concrete (SCC) using fly ash (FA) and silica fume (SF) as Supplementary Cementitious Materials (SCMs). The results of scanning electron microscopy and energy dispersive spectroscopy illustrate the formation of uniformly distributed and compact C-S-H gel in presence of CS after 120 d, with Ca/Si ratio ranging between 0.77 and 1.11. The SCC mix with 100% CS substitution was found to be most economical with least consumption of embodied energy and emission of embodied carbon dioxide. This study authenticates that CS in combination with SCMs is promisingalternative over the conventional sand in construction industry.

Nandrade *et al.* [3] Says The present work focuses on assessing the viability of applying blasted copper slag, produced during abrasive blasting, as fine aggregate for Portland cement concrete manufacturing, Assays showed a significant improvement in workability, with the increase in substitution offline aggregate. With 80% of replacement, the concrete presented lower levels of water absorption capacity. Axial compressive strength and diametrical compressive strength decreased, with the increase of residue replacement content. The greatest reductions of compressive strength were found when the replacement was over 40%. For tensile strength by diametrical compression.

Al-jabri *et al.* [4] says the effect of using copper slag as a fine aggregate on the properties of cement mortars and concrete. Various mortar and concrete mixtures were prepared with different proportions of copper slag ranging from 0% (for the control mixture) to 100% as fine aggregates replacement. addition of more copper slag resulted in strength reduction due to the increase in the free water content in the mix. The results demonstrated that surface water absorption decreased as copper slag content increases upto 50% replacement. Beyond that, the absorption rate increased rapidly and the percentage volume of the permeable voids was control.

4. Experimental Work

The materials used are

1. Cement – Here we used Ordinary Portland cement 53 grade used.
2. Silica Fume - Silica fume is produced during a high-temperature reduction of quartz in an electric arc furnace when the main product is silicon or ferrosilicon. The chemical process is complex and it depends on the temperature of the producing.
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 end product is a solid, hard material that goes to the crusher for further processing. Copper slag used in this work was bought from Ujjwal industries (India) Pvt.ltd, Ahmednagar, India.
4. Fine aggregates - Locally available sand was used as fine aggregate. The specific gravity of fine aggregate is 2.6.
5. Coarse aggregates - Crushed granite metal with 12.5 mm and retained on 10 mm sieve was used and also 20 mm was used. The sieve analysis of the aggregates was carried out and the same distribution

Table 1: Physical Properties of copper slag

Physical Properties	Copper Slag
Particle shape	Irregular
Appearance	Black and glassy
Type	Air cooled
Specific gravity	3.91
Percentage of voids %	35
Bulk density g/cc	2.08
Fineness Modulus	3.47
Angle of internal friction	51° 20‟
Fineness m2 /kg after grinding)	125
Moisture content %	0.1
Water absorption %	0.16
Ultimate shear stress kg/cm2	2.08

Table 2: Chemical Properties of copper slag as per Ujjwal Industries Pvt. Ltd.

Sr. No.	Chemical Component	% of Chemical Component
1.	SiO2	25.84
2.	Fe2O3	68.29
3.	Al2O3	0.22
4.	CaO	0.15
5.	Na2O	0.58
6.	K2O	0.23
7.	Mn2O3	0.22
8.	TiO2	0.41
9.	SO3	0.11
10.	CuO	1.20
11.	Sulphide Sulphur	0.25

Table 3: Properties of Silica fume as per Yonsons Eng. Pvt. Ltd.

Properties	Results
SiO2	>97%
SO3	0.4
Al2O3	0.5%
Colour	Premium white
Specific gravity	2.2
Particle size	1µ
Bulk density	576 kg/m3
Surface area	20000 m2/kg
Fineness	3 %

5. Experimentation and Tests

i) Mix Proportioning

The mix design is done according to the IS design method Concrete Mixes In this study, the early age properties of fresh concrete and mechanical performance and tensile strength of hardened concrete were examined. All tests were conducted using the following sample groups:

1. An ordinary cement paste or concrete,
2. Pastes or concrete substituted with 6%, 8%, 10%, 12% SF by mass of cement
3. Pastes or concrete substituted with 5%, 10%, 15%, 20% CS by mass of sand
4. Pastes or concrete substituted with 5% SF by mass of cement and 20% CS by mass of sand.

ii) Mixing procedure

The mixing procedures are divided into three stages. In the first stage, all the binders (cement, silica fume, copper slag) were weighted accordingly and mixed by hand until all the constituents mixed uniformly. This is to make sure all the binders are mixed thoroughly to produce a homogenous mix. The second stage involves mixing the binders with the aggregates for about 5 minutes. At the final stage, measured water is added into the concrete mix. This step is crucially important to make sure that the water is distributed evenly so that the concrete will have similar water-binder ratios for every cube. After that, the concrete was then poured into the mould. Preparing test cubes.

The size of the mould is 150 x 150 x150 mm used to produce the 30 cubes were used for each concrete mix. The concrete was poured into the mould in two layers where each layer was compacted using a steel bar. The cubes were removes from the moulds after 24 hours and cured using sacks in room temperature.

iii) Preparing test cylinders

The size of cylinder used for split tensile strength and durability studies was 150mm diameter and 300mm height. This test was conducted in accordance with IS: 5816-1999. The crude oil was applied along the inner surfaces of the mould for the easy removal of specimens from the mould. Concrete was poured throughout its length and compacted well.

iv) Curing

In this study cubes were cure by dipping the specimen
In water 25˚C at the end of 24 hours of casting after alloying allowing for air drying.

v) Experimental procedures

Compressive strength test Concrete cubes of size 150mm×150mm×150mm were cast with and without copper slag. During casting, the cubes were mechanically vibrated using a table vibrator. After 24 hours, the specimens were demoulded and subjected to curing for 28 days in portable water. After curing, the specimens were tested forcompressive strength using compression testing machine of 2000KN capacity. The maximum load at failure was taken. The average compressive strength of concrete and mortar specimens was

6. Result and Discussion

The Compressive Strength of M40 Concrete Specimen cube Testing Results Variation in 5%, 10%,15%,20% replacement of Copper Slag and 6%,8%,10%,12% replacement of Silica fume are following:

Table 4: Flexural & Split Tensile Strength Test of Replacement % of Copper Slag

% Replacement of Copper Slag	3days Compressive Strength	7days Compressive Strength	28days Compressive Strength
5%	23.5	31.03	44.63
10%	25.54	34.94	49.81
15%	25.89	36.44	52.14
20%	27.55	36.45	54.15

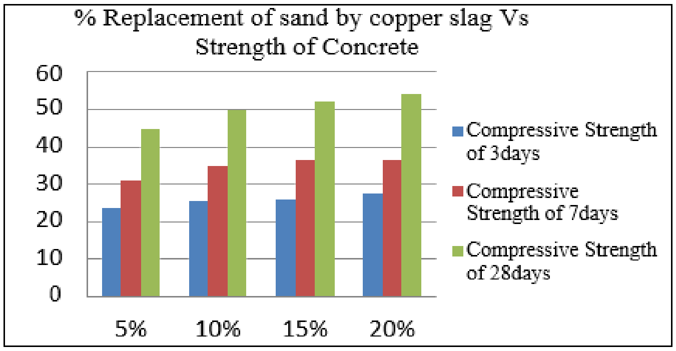

Fig 1: Compressive Strength result of partially replacement by Copper Slag for Sand in Concrete

Table 5: Flexural & Split Tensile Strength Test of Replacement % of Copper Slag

% Replacement of Copper Slag	28 Days Split Tensile Strength (N/mm2)	28 Days Flexural Strength (N/mm2)
5%	3.96	4.75
10%	4.7	4.9
15%	4.4	5.21
20%	4.45	5.78

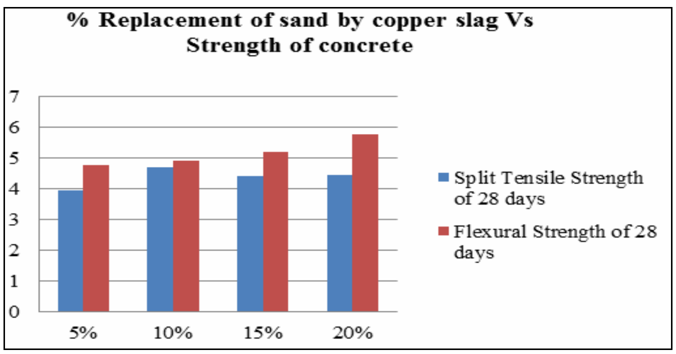

Fig 2: Split Tensile Strength & Flexural Strength Test result of partially replacement by Copper Slag for Sand in Concrete

Table 6: Compressive Strength Test of Replacement % of Silica Fume

% Replacement of Silica Fume	7days compressive strength	28days compressive strength
6%	29.46	41.89
8%	30.6	44.25
10%	33.66	48.89
12%	32.54	46.25

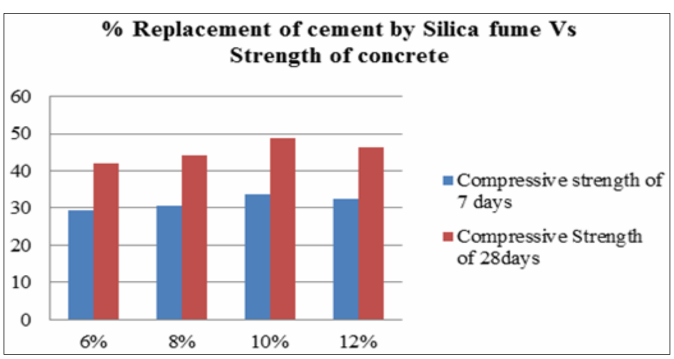

Fig 3: Compressive Strength result of partially replacement by Silica Fume for Cement in Concrete

Table 7: Flexural & Split Tensile Strength Test of Replacement % of Silica Fume

% Replacement of Silica Fume	28 Days Split Tensile Strength(N/mm2)	28 Days Flexural Strength(N/mm2)
6%	4.75	7.9
8%	5.24	9.5
10%	5.75	9.1
12%	4.43	8.13

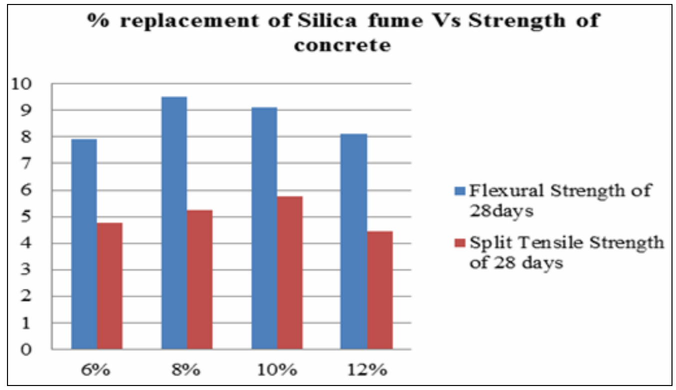

Fig 4: Split Tensile Strength & Flexural Strength Test result of partially replacement by Silica Fume for Cement in Concrete.

7. Conclusion

From this paper we can conclude that,

1. It has been observed that maximum compressive strength is noted for 10% replacement of silica fume than normal concrete.
2. It has been observed that maximum compressive strength is noted for 20% replacement of Copper Slag than normal concrete.
3. Consistency of cement depends upon its fineness. Silica fume is having greater fineness than cement and greater surface area so the consistency increases greatly, when silica fume percentage increases.
4. The optimum 28-day Split Tensile and flexural strength have been obtained in range of 10-15 % silica fume replacement level.
5. The optimum 28-day Split Tensile and flexural strength have been obtained in range of 10%silica fume replacement level.

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