STUDY ON COPPER SLAG AND MICRO SILICA EFFECTS IN CONCRETE

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Abstract

The purpose of this research is to find the suitability of copper slag as an alternative material for the river sand. This experimental study was divided into four phases, where in the first phase physical properties of cement, aggregates, Silica Fume and copper slag were examined. In the second phase, M30 grade of concrete is chosen to perform the effective replacement of copper slag with fine aggregate by replacement levels of 0%, 25%, 50% and 75% and the behaviour of fresh and hardened properties of concrete was carried out. Cement is replaced by Silica Fume for 5%, 10% and 15% were used in the concrete by weight of cement. This project will present the results of an experimental study on various Compressive strength, Split tensile strength, Workability test and Durability on concrete containing copper slag and micro silica as partial replacement of sand and Cement respectively.

From the test results, it was concluded that cube compressive strength, split tensile strength and Flexural Strength of concrete had higher strength for 25% replacement of copper slag with 10% Silica Fume. Copper slag replacement at 50% & 75% with Silica Fume showed a marginal variation in cube compressive strength, Split tensile strength and Flexural Strength.

Keywords: Compressive strength, Tensile Strength, Flexural Strength, copper slag, Silica Fume, Mechanical Properties, Self-compacting concrete.

1. INTRODUCTION

Conventional concrete, a versatile material can be prepared by mixing the ingredients cement, river sand and coarse aggregate with required water cement ratio. Cementing medium is a product of reaction chemically, between water and hydraulic cement. Concrete is made with several types of cement and also containing pozzolana, blast furnace slag, sulphur, a regulated set additive, polymers, admixtures, fibers etc. Workability is an amount of useful internal work which is necessary to produce full compaction which is a physical property of concrete and the work or energy required to overcome the internal friction between the individual particles, formwork surface or reinforcement provided in the concrete.

Concrete has become inevitable material in human life due to its extensive usage in modern construction activities and its properties like strength and durability. India has taken a sound decision on infrastructural development in 21st century, such as express highways, airports, ports, power projects and tourism projects. In every construction activity involves with concrete, hence concrete plays a vital role in present scenario of construction industry. Wide range usage of concrete is in infrastructural development because of its characteristics. The usage of available natural resources and the consequent requirement of energy for the processing has become a serious economic impact.

By different ingredients of concrete, depending upon the purpose and use, the properties of concrete can also be changed or varied. Since the shielding ability and attenuation capacity are not influenced by the type of material and it depends on density of concrete, it is essential to increase the mass of concrete per unit. Concrete has relatively higher compressive strength but very lower tensile strength. For this cause, it is usually reinforced with materials to make it sound in tension (often steel). Concrete can be damaged by many actions, such as freezing of trapped water, permeability in concrete composition. To overcome the damage of concrete, proper quality of ingredients shall be used in the concrete composition. Due to the vast usage of concrete in this century, concrete ingredients are depleting stage. Hence, production of quality concrete is quite difficult with low quantity of quality ingredients. So, recycling, reuse and substitution of ingredients are one solution to overcome shortage of quality aggregates.

2. LITERATURE REVIEW

Bipragorai et al (2003) made a comprehensive review on the characteristic properties as well as various processes of copper slag such as hydro, pyro and combination of pyro-hydrometallurgical methods in recovery of metals and the production of value added products from the copper slag. It is produced during the pyro metallurgical manufacturing of copper from copper ores, contains components like alumina, iron, silica, calcium oxide, etc. This paper demonstrates the favorable physio-mechanical properties of copper slag which can be utilized to produce products like cement, aggregate, ballast, fill, abrasive, tiles, roofing granules, glass, etc. apart from recovering the metals by different extractive metallurgical processes. The favorable chemical and physio-mechanical characteristics of copper slag lead to effective utilization to produce various value added products such as cement, aggregate, ballast, fill, abrasive, tiles, roofing granules, glass, etc. The effective utilization of copper slag in such procedures may lead to reduction in the cost of disposal and leads to less environmental problems.

Caijun Shi et al (2008) studied the characteristics of copper slag on the mechanical properties of cement, mortars and concrete and concluded that by the use of copper slag in cement and concrete, gives an additional environmental and technical benefits for all industries, especially in the areas where considerable quantities of copper slag are produced. When copper slag is replaced with cement or aggregates, the cement, mortar and the concrete which contains various forms of copper slag will have good performance when compared with ordinary Portland cement which is having normal strength and even higher strength.

Al-Jabri (2009) studied the effect of replacement of copper slag with sand on the mechanical properties of high performance concrete (HPC). A total of eight concrete mixtures were made with different percentages of copper slag from 0% (for control mix) to 100% with 10% intervals. The Concrete mixes were tested for density, workability, compressive strength, split tensile strength, flexural strength and durability of concrete. The results showed a slight increase in HPC density of nearly 5% with increase of copper slag quantity, whereas a rapid increase in workability with an increases of copper slag content. An addition of copper slagup to 50% as sand replacement gave comparable strength when compared with controlled mix. Hence, further increments of copper slag resulted in reduction of strength due to increase of free water content in mix. Concrete mixes with copper slag of 80% and 100% replacement gave lowest compressive strength approximately 80 MPa, nearly 16% lower than controlled mix. These results also demonstrated that with increases of copper slag upto 40%, surface water absorption decreased; beyond the level of replacement, the absorption rate will increase rapidly.

3 MATERIALS AND PROPERTIES

3.1 Cement

Cement plays vital role in concrete. One of the important criteria tricalcium aluminate (C_3A) content, tricalcium silicate (C_3S) content, dicalcium silicate (C_2S) content etc. It is also necessary to ensure the compatibility of chemical and mineral admixtures with cement.

In this study, Zuari Cement of 53 grade Ordinary Portland Cement conforming to IS: 12269–1987 was used for the entire work. The cement was purchased from single source and was used for casting of all specimens. The physical properties of cement are furnished in Table No.1

Table 1 physical properties of cement

S.No	Characteristics	Test Results	Requirements as per IS 12269 - 1987
1	Fineness (retained on 90-µm sieve)	6%	<10%
2	Normal Consistency	32%	--
3	Initial setting time of cement	70 min's	30 minutes (minimum)
4	Final setting time of cement	350 min's	600 minutes (maximum)
5	Expansion in Le-chatelier's method	3 mm	10 mm (maximum)
6	Specific gravity	3.12	3.10 – 3.25

3.2 FINE AGGREGATE

The natural sand taken for this investigation is the locally available natural river sand. It was collected and cleaned for impurities, so that it is free from clayey matter, salt and organic impurities. Particles passing through IS sieve of 4.75 mm conforming to grading zone-II of IS: 383-1970 were used in this work. Properties such as gradation, specific gravity, fineness modulus, bulking, and bulk density had been assessed. The physical properties of sand are furnished in Table 2.

Table2 physical properties of Fine Aggregate

S.No.	Tests Conducted	Results Obtained		Permissible Limits as per IS 383-1970
1	Specific gravity	2.60		2.5 to 3.0
2	Fineness modulus	2.77		--
3	Bulk density	**Loose State**	1450kg/m^3	1400 to 1750 kg/m3
		Compacted State	1520 kg/m^3	
4	Water absorption (%)	1.09		Max 3%
5	Sieve Analysis	Zone – II		--

3.3 COARSE AGGREGATE

Locally available machine Crushed angular granite, retained on 4.75mmI.S. sieveof maximum size of 20mm confirming to I.S: 383-1970 was used in the present experimental investigation. It is free from impurities such as dust, clay particles and organic matter etc. The coarse aggregate is tested for its various properties such as specific gravity, fineness modulus, elongation test, flakiness test, sieve analysis, bulk density in accordance with in IS 2386 – 1963. The physical properties of Coarse Aggreagte are furnished in Table 3.

Table3 physical properties of Coarse Aggregate

S.No.	Tests Conducted	Results Obtained		Permissible Limits as per IS 383-1970
1	Specific gravity	2.72		2.5 to 3.0
2	Fineness modulus	7.1		--
3	Bulk density	**Loose State**	1480 kg/m^3	1400 to 1750 kg/m3
		Compacted State	1560 kg/m^3	
4	Water absorption (%)	1..20		Max 3%
5	Flakiness Index	20%		Max 25%
6	Elongation Index	22%		Max 25%

3.4 WATER

Water used for mixing and curing shall be clean and free from injurious quantities of alkalies, acids, oils, salts, sugar, organic materials, vegetable growth (or) other substance that may be deleterious to bricks, stone, concrete, or steel. Potable water is generally considered satisfactory for mixing.

Water acts as a lubricant for the fine and coarse aggregates and acts chemically with cement to form the binding paste for the aggregate and reinforcement. Less water in the cement paste will yield a stronger, more durable concrete; adding too much water will reduce the strength of concrete and can cause bleeding.

Impure water in concrete, effects the setting time and causing premature failure of the structure.

To avoid these problems quality (potable) water must be proffered in construction works and PH value of water should be not less than 6. And also Quantity of water to betaken is important

3.5 COPPER SLAG:

Copper Slag, is a black glassy and granular in nature and has a similar particle size range like sand. It is an industrial by-product obtained during the smelting of copper. Copper slag used in this work was from Sterlite Industries (India) ltd, Tuticorin, Tamil Nadu, which was collected from the supplier Copag Abrasives and Minerals, Tuticorin, Tamil Nadu, Indiathe physical properties of copper slagare presented in the Table – 4

Table 4 Physical properties of Copper slag

Characteristics	Test Results
Specific gravity	3.91
Fineness modulus	3.47

3.6 SILICA-FUME

Silica-Fume is a highly pozzolanic mineral admixture, which is mainly utilized to improve concrete strength and durability of concrete. Silica-Fume reacts with calcium hydroxide formed during hydration of cement results in the increase in strength and also the Silica-Fume fills the voids between cement particles leads to increase in the durability.The physical properties of chemical admixture are furnished in table –5.

Table 5 Physical properties of chemical admixture

S.No	Characteristics	Test Results
1	Pozzolanic Activity Index (Min)	Light brown liquid
2	Specific surface Area (m^2/gm)	0.08+/-0.01 at 250°C
3	Bulk density (Kg/m^3)	≥6
4	> 45 Microns (Max)	<0.2%

3.7 MIX PROPORTIONS

Table 6 - Quantities of Ingredients per Cum of M30 Grade Concrete

Mix Identification	Cement (kg's)	Fine Aggregate		Coarse Aggregate (kg's)	Water (lit)	Silica Fume (kg's)
		Sand (kg's)	Copper Slag(kg's)			
C.C	360	688	0	1225	177	0
25% C.S	360	517	262	1225	183	0
50% C.S	360	344	524	1225	181	0
75% C.S	360	172	786	1225	179	0
25% C.S + 5% S.F	342	517	262	1225	183	15
25% C.S + 10% S.F	324	517	262	1225	183	30
25% C.S + 15% S.F	306	517	262	1225	183	45
50% C.S + 5% S.F	342	344	524	1225	181	15
50% C.S + 10% S.F	324	344	524	1225	181	30
50% C.S + 15% S.F	306	344	524	1225	181	45
75% C.S + 5% S.F	342	172	786	1225	179	15
75% C.S + 10% S.F	324	172	786	1225	179	30
75% C.S + 15% S.F	306	172	786	1225	179	45

4 EXPERIMENTAL INVESTIGATION

4.1 CONCRETE MIX PREPARATION\

Design of concrete mix requires complete knowledge of various properties of the constituent materials. Initially the ingredients such as cement and fine aggregate were mixed, to which the coarse aggregate are added followed by addition of water and thoroughly mixed. Prior to casting of specimens, workability is measured in accordance with the code IS 1199-1959 by slump cone test.

4.2 CUBE COMPRESSION STRENGTH TEST

Compression test is the most common test conducted on hardened concrete, because it is an easy test to perform, and most of the properties of concrete are qualitatively related to its compressive strength. Compression test is carried out on specimen of cubical or cylindrical in shape. Compression test is done confirming to IS: 516-1959. All the concrete specimens were tested in compression-testing machine. Concrete cubes of size 150mm × 150mm × 150mm were tested for Compressive Strength.

4.3 SPLIT TENSILE STRENGTH

Split Tensile Strength test was conducted on cylindrical specimens at 28days as per IS 5816-1999. Three cylindrical specimens of size 150 mm × 300 mm were casted. Split tensile strength of concrete is determined by applying the load at the rate of 140kg/sq.cm/minute till the specimens failed. The maximum load applied was then noted.

The splitting tensile strength (Ft) was calculated as follows:

$$Ft = \frac{2P}{\pi DL}$$

Where, P = Compressive load

L = Length of the cylinder

D = Diameter of the cylinder

4.4 FLEXURAL STRENGTH TEST

Flexural strength is a measure of tensile strength of concrete of an unreinforced concrete beam to resist failure in bending. The flexural strength can be determined by Standard test method. In this study, three beams of size 100 mm × 100 mm × 500 mm were used to find flexural strength.

5 RESULTS AND DISCUSSIONS

5.1 COMPRESSIVE STRENGTH

Fig 1 showscomparison of cube compressive strength with the controlled concrete by replacing copper slag at 25%, 50% and 75% with sand. the maximum cube compressive strength was found for 25% replacement of copper slag with sand at 28 days age of concrete compared to 50% and 75% percent replacement of copper slag. In all the mixes, there is a decrease in the compressive strength of concrete compared to ControlIt can be observed that the compressive strength of concrete prepared by replacing copper slag and Silica Fume exhibits more strength than the control concrete at all replacement levels. It is also observed that concrete prepared with 25% Copper Slag (CS) and 10% of Silica Fume (SF) exhibits maximum Compressive Strength. Finally, copper slag can be effectively replaced with sand up to 25%, also Silica Fume can be replaced up to 10% by weight of cement.

Fig 2 showscomparison of cube compressive strength with the controlled concrete by replacing copper slag at 25%, 50% and 75% with Silica Fume 0%, 5%, 10% & 15%.

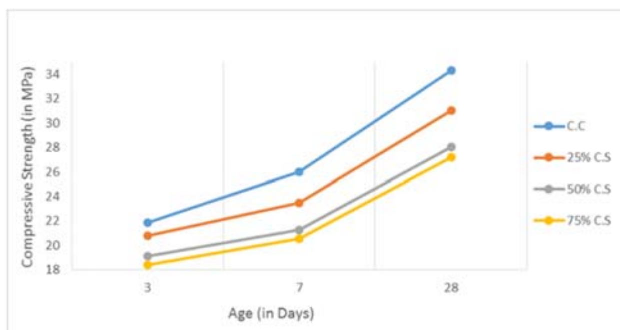
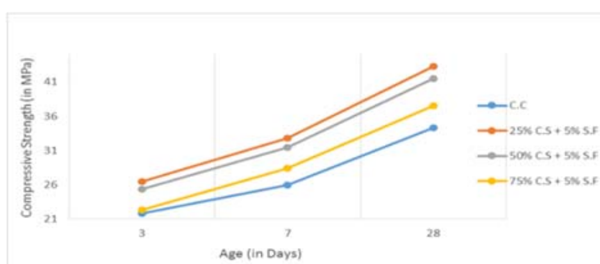
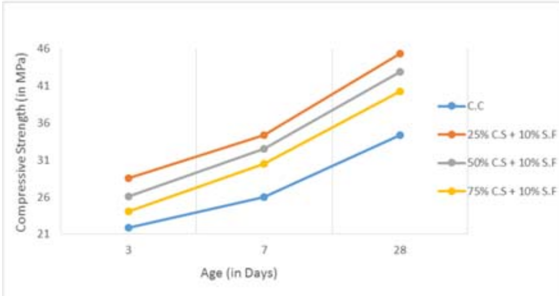


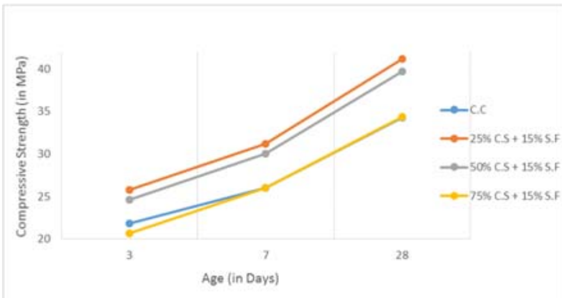
Fig No.1 Variation of cube compressive strength with the controlled concrete by replacing copper slag at 25%, 50% and 75% with sand



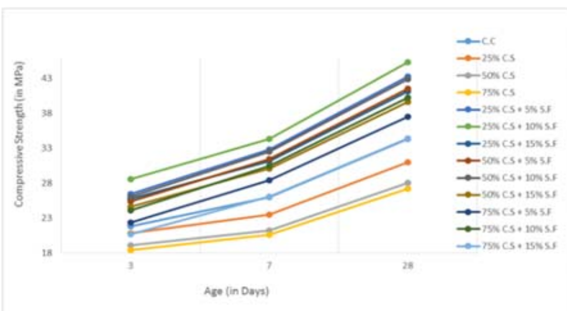
(i) 5% SF



(ii) 10% SF



(iii) 15%



(iv) All Percentages of CS + SF

Fig No.2Variation of cube compressive strength with the controlled concrete by replacing copper slag and Silica Fume

5.1.2 SPLIT TENSILE STRENGTH

Figure 3 shows the comparison of Split Tensile strength with various percentages of Copper Slag and Silica Fume at 28 day's age of concrete The split tensile strength of control concrete is 3.56MPa. The split tensile strength of concrete increased at 25% of copper slag with 10% of Silica Fume to 3.90. It was observed that, the split tensile strength of concrete was increased with all Combined applications of copper slag and Silica Fume except for the Copper Slag replacements (25%, 50% & 75%) compared to Control Concrete

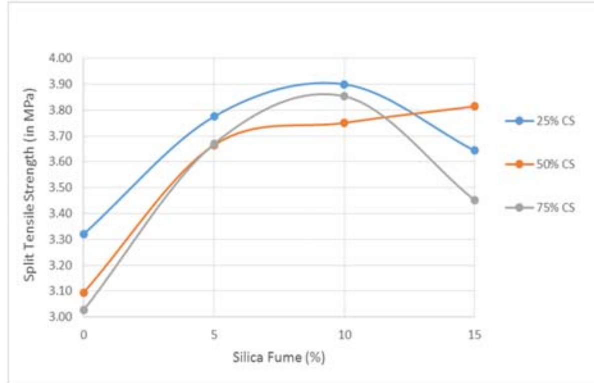


Figure 3 showing the comparison of Split Tensile strength with various percentages of Copper Slag and Silica Fume at 28 day's age of concrete

5.1.3 FLEXURAL STRENGTH

Figure 4 shows the comparison of Flexural strength with various percentages of Copper Slag and Silica Fume at 28 day's age of concrete. With the addition of Silica Fume all the mixes had got the maximum flexural strength. By the addition of 10% Silica Fume, there is an increase of flexural strength when compared with controlled concrete. At 15% addition of Silica Fume, there is also increase in the flexural strength of concrete compared to the controlled concrete at 28 days age of concrete. There was more improvement in the flexural strength of concrete at 25% replacement of copper slag with 10% Silica Fume when compared to control mixes.

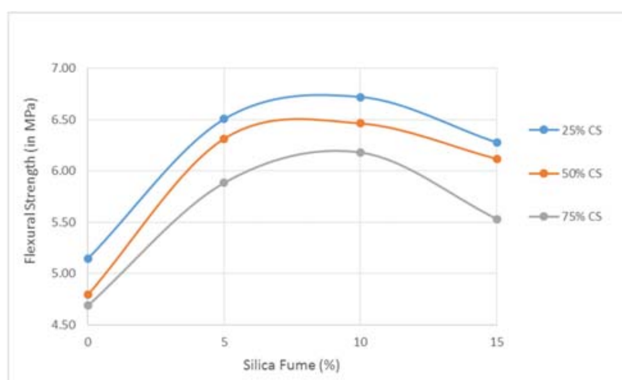


Figure 4 showing the comparison of Flexural strength with various percentages of Copper Slag and Silica Fume at 28 day's age of concrete

6 CONLUSIONS

1. From the test results, it was concluded that cube compressive strength, split tensile strength and Flexural Strength of concrete had higher strength for 25% replacement of copper slag with 10% Silica Fume.

2. Copper slag replacement at 50% & 75% with Silica Fume showed a marginal variation in cube compressive strength, Split tensile strength and Flexural Strength.

3. There was more improvement in the flexural strength of concrete at 25% replacement of copper slag with 10% Silica Fume when compared to control mixes.

4. Full replacement of copper slag cannot be allowed with and without Silica Fume as there was a drastic down fall in the cube compressive strength, split tensile strength and flexural strength than the controlled concrete.

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