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INVESTIGATION ON STRENGTH PROPERTIES OF SELF COMPACTING CONCRETE WITH COPPER SLAG AS FINE AGGREGATE

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ABSTRACT

Utilization of industrial waste materials has encouraged in construction field for the making of concrete because it contributes to reducing the consumption of natural resources. Self – compacting concrete (SCC) is a high – performance concrete which can flow under its own weight and it fills the form work thoroughly and self-consolidates without any additional mechanical vibration. Such concrete can accelerate the placement and reduce the labour needs for compaction and finishing. Copper slag is considered as one of the waste materials which can have a hopeful expectation in construction industry as partial or full alternative of aggregates. The objective of this work is to study the strength properties of self-compacted copper slag concrete. For this purpose M30 grade concrete was used and test were conducted for various proportion of sand replaced by copper slag at 0%, 20%, 40%, 60%, 80%, 100% and silica fume were used as an admixture to the concrete.

Keywords: Packing factor, Passing ability, Filling ability.

INTRODUCTION

When large quantity of heavy reinforcement is to be placed in a reinforced concrete member, it is hard to ensure that the formwork gets totally filled with concrete that is, completely compacted without any honeycombs. It is not easy to do the compaction by manual or by mechanical vibrators in this situation. The representative method of compaction, vibration, generates delays and extra cost in the projects. This difficulty can now be solved with self-compacting concrete. This type of concrete can flow easily around the reinforcement and into all corners of the formwork. Self-compacting concrete (SCC) describes a concrete with the ability to compact itself only by means of its own weight without the requirement of vibration.The exclusion of vibrating equipment enhance the environment on and near construction where concrete is being placed, sinking the coverage of labour to noise and vibration. Self-compacting concrete is also known as Self-consolidating concrete or self-leveling concrete.

Large amount of industrialized waste mount up annually in the emerging countries. Viability and resource effectiveness are escalated by most important issues in today's construction industry. Therefore, these days use of alternate materials is commonly used in construction industry. Copper slag is one of the waste materials which possibly will have a hopeful future in construction field as alternative of either cement or aggregates. European Federation of natural trade associations representating producers and applicators of specialist building products (EFNARC) has drawn up specification and guidelines for self-compacting concrete to provide a framework for designing and the use of high quality SCC during 2002.The design mix of self-compacting concrete based on M30 is prepared and studied for various replacements of fine aggregates by copper slag and it is evaluated for its strength properties.

MATERIAL PROPERTIES

Cement:

The cement used in this study was 53 grade ordinary Portland cement (OPC).The properties of cement used are given in Table 1.

Table1: Physical Properties of Cement

S. No	Properties	Result
1	Fineness of cement	2%
2	Normal Consistency	31.28%
3	Initial setting time of cement	37 minutes
4	Final setting time of cement	590 minutes
5	Specific gravity	3.15

Coarse Aggregate:

Locally available 16mm size well graded coarse aggregate were selected for present work. The various properties of coarse aggregates were determined and tabulated in Table 2.

Table2: Properties coarse aggregate

S. No	Properties	Result
1	Fineness Modulus	3.46
2	Specific Gravity	2.695
3	Bulk Density	1450 kg/m^3
4	Moisture Content	0.25%
5	Water Absorption	0.4%

Fine Aggregate:

Fine aggregate used was river sand passing through IS sieves 4.75 mm obtained from a local source. Various properties of fine aggregates are listed in table 3.

Table3: Properties of fine aggregate

S. No	Properties	Result
1	Fineness Modulus	3.18
2	Specific Gravity	2.624
3	Bulk Density	1500Kg/m^3
4	Moisture Content	2.4%
5	Water Absorption	0.8%

Copper Slag:

Copper slag was collected from Sterlite Industries India Limited (SIIL) Tuticorin, Tamil Nadu, and used in the present work. Various physical and chemical properties of copper slag are listed in the table below:

Table4: Physical properties of copper slag.

Physical Properties	Copper Slag
Particle shape	Irregular
Appearance	Black and glassy
Specific gravity	3.93
Percentage of voids %	34
Water absorption %	0.18
Moisture content %	0.13
Fineness Modulus	3.28
Bulk density	1900 Kg/m^3

Table5: Chemical properties copper slag

Chemical Composition	% of Chemical Component
SiO_2	23.43
Fe_2O_3	65.23
Al_2O_3	0.20
CaO	0.13
Na_2O	0.52
K_2O	0.28
Mn_2O_3	0.25
TiO_2	0.51
SO_3	0.16
CuO	1.22
Sulphide sulphur	0.15
Insoluble residue	10.22

Silica Fume:

Silica fume can be added to Portland cement concrete to extend its properties; especially it improves its compression and bonding strength, and gives better abrasion resistance. Silica fume is very fine non crystalline silica is produced in electric arc furnace as a derivative of the production of elemental silicon or alloys containing silicon. It is usually a grey coloured powder, somewhat similar to Portland cement. Silica fume of specific gravity 2.2 is used in this study. Because of its intense fineness and high silica content, silica fume acts as a very effective pozzolanic material.

Super plasticizer:

The use of super-plasticizers in concrete is a mile stone in the advancement of concrete technology super-plasticizers. Some high range water reducing admixtures can retard final set by one to four hours and if prolonged setting times are not convenient, the admixture can be combined with an accelerating admixture to counteract the retarding tendencies or even to provide some acceleration of setting. In this present works super plast 840 super plasticizer is used to make concrete more workable with the self compacting charecteristics.

Water:

Water is an important ingredient in concrete. Practically all natural water that is safe to drink and has no distinct taste or smell which can be used for mixing water in making concrete. Some water which may not fit for drinking may also still be harmless for mixing concrete. Potable water available from the local source was used in the work.

MIX PROCEDURE

By varying the volume of fine aggregate and coarse aggregate several trail mixes are carried out according to the limitation stipulated in the EFNARC guidelines to satisfy fresh properties. Based on this optimum mix is determined. Mix design calculations are based on several characteristic properties like packing factor, bulk density of loose aggregates, specific gravity, etc. Packing factor is the ratio of mass of aggregates of tightly packed state in SCC to loose state in air. Packing Factor of 1.12 is taken on trial basis. Quantity of cement and water required for cement mixing is calculated as per ACI method. The Quantity of other materials is calculated by Nansu tool for mix design (2001). The percentage of fine aggregate is replaced by 0%, 20%, 40%, 60%, 80%, and 100% in the obtained optimum mix and checked for their fresh and hardened properties. Fresh properties, typical acceptance criteria and mix proportions of the self compacting concrete are tabulated in Table 7, 8 and 9.

Table 7: Fresh Properties of SCC

Mix	Slump (mm)	Slump 50 (sec)	V funnel (sec)	Jring (mm)	remark
0%	700	2	7	2	satisfied
20%	700	2	7	3	satisfied
40%	700	2	8	4	satisfied
60%	680	3	12	8	satisfied
80%	480	Not satisfied			

Table 8: Typical Acceptance Criteria for SCC

S. No	Method	Unit	Typical range	
			Min.	Max
1	Slump flow test (Filling ability)	mm	650	800
2	T50cm slump flow (Filling ability)	sec	2	5
3	V-funnel test (Filling ability)	sec	8	12
4	J-ring (Passing ability)	mm	0	10

Table 9: Mix Proportion.

Mix	Cement (Kg/m^3)	Fine aggregate (Kg/m^3)	Copper slag (Kg/m^3)	Coarse Aggregate (Kg/m^3)
0%	394	974	-	682.08
20%	394	780	246	682.08
40%	394	585	494	682.08
60%	394	389	740	682.08
80%	394	195	984	682.08

HARDENED PROPERTIES

Hardened concrete properties such as compressive strength, spilt tensile strength and flexural strength are tested. For that 3 cubes of size (150*150mm), 3 cylinders of (300*150mm) and 3 prisms of size (500*100*100) are cast for each trial mixes of copper slag replacement and tested after 7, 14 and 28 days of curing. Test results are listed in Tables 10, 11 & 12.

Table10: Compressive Strength

Specimen	Compressive strength (N/mm^2)		
	7th day	14th day	28th day
CS 0	29.78	32.7	35.55
CS 20	31.11	34.5	37.7
CS 40	33.78	37.44	42.8
CS 60	35.56	40	45.3
CS 80	26.67	30.6	33.5

Table11: Split Tensile Strength

Specimen	Split tensile strength (N/mm^2)		
	7th day	14th day	28th day
CS 0	1.62	1.62	1.62
CS 20	1.87	1.87	1.87
CS 40	2	2	2
CS 60	2.07	2.07	2.07
CS 80	1.7	1.7	1.7

Table12: Flexural Strength.

Specimen	Flexural strength (N/mm^2)		
	7th day	14th day	28th day
CS 0	3.87	4.25	4.6
CS 20	4.33	4.57	5.3
CS 40	5.00	5.63	6.2
CS 60	5.70	6.03	6.5
CS 80	3.80	4.30	5.1

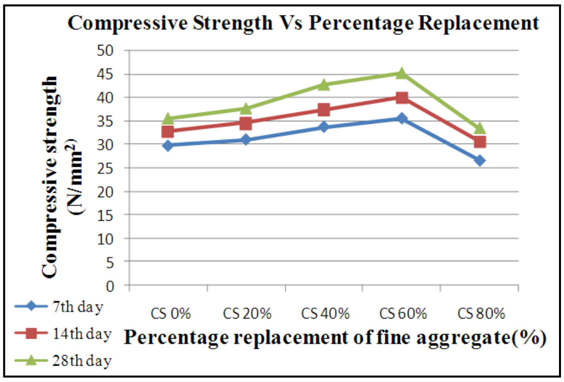

Figure 1 Compressive Strength Vs Percentage Replacement

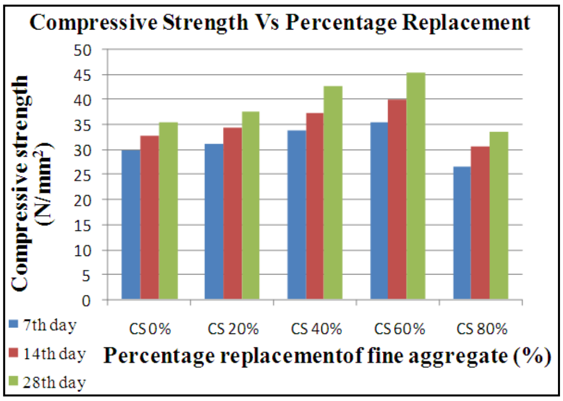

Figure 2 Compressive Strength Vs Percentage Replacement

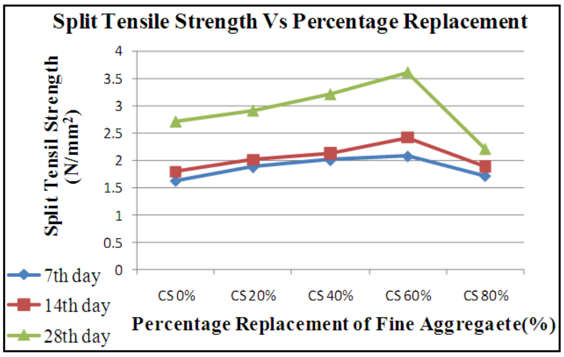

Figure 3 Compressive Strength Vs Percentage Replacement

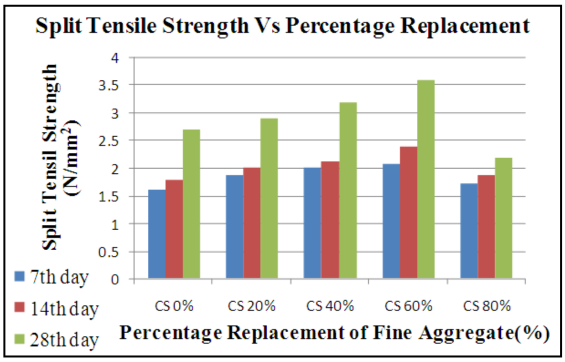

Figure 4 Compressive Strength Vs Percentage Replacement

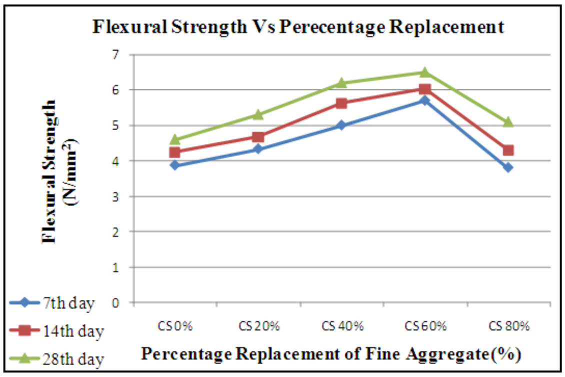

Figure 5 Flexural Strength Vs Percentage Replacement

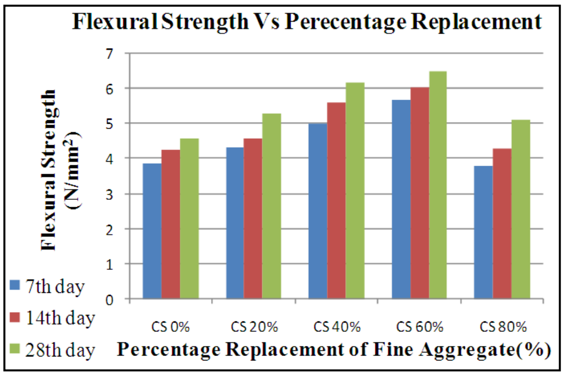

Figure 6 Flexural Strength Vs Percentage Replacement

From figure 1 to 6, the results clearly show that the self compacting concrete with 60% copper slag is replaced for fine aggregate has optimum results in compressive, split tensile and flexural strength. At 60% Copper slag replacement, the compressive strength, split tensile strength and flexural strength hence an improvement of 27%, 28% and 41% respectively to that of the strengths of control concrete.

CONCLUSION

1. From the experimental results, it was observed that the compressive strength, split tensile strength and flexure strength of concrete can be improved by partial replacement of fine aggregate with copper slag and was found that 60% replacement gives optimum results.

2. The highest compressive strength obtained was 45.3 MPa (60% replacement @ 28 days) which is higher than that of the corresponding strength for control SCC 35.55 MPa.
3. The percentage of increase in the compressive strength is 27.42% after a span of 28 days by replacing 60% of fine aggregate with copper slag.
4. The percentage of increase in the split tensile strength is 33.3% after a span of 28 days by replacing 60% of fine aggregate with copper slag.
5. Further detailed research work is needed to explore the effect of copper slag as fine aggregates.

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