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An Experimental Study on Glassfibre Reinforced Self Compacting Concrete Using Copper slag as a Partial Replacement of Fine Aggregate

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Abstract— Development of self-compacting concrete (SCC) is a desirable achievement in the construction industry in order to overcome problems associated with cast-in-place concrete. since, common river sand is expensive and also large scale depletion of these sources creates environmental problems, a substitute or replacement product for concrete industry is the need of the hour. In such a situation, the Copper Slag can be an economic alternative to the river sand, which is an industrial by-product obtained from the manufacturing of copper. SCC was added with relatively short, discrete, and discontinuous glass fibres to produce Glass Fibre Reinforced Self Compacting Concrete (GFRSCC), to avoid cracking on loading due to low tensile strength of concrete. The use of glass fibres in SCC improves the engineering properties such as tensile strength, ductility, post crack resistance and energy absorption capacity. This work aims at the partial replacement of sand by copper slag and the strength variations observed by the incorporation of glass fibres are studied and compared with the strength properties of control mix SCC. Mix proportioning has to be done for M30 SCC and Self Compactability is checked by various flow tests of slump flow test, J-ring test, U-box, V-funnel and L- Box. Sand is replaced with copper slag in proportions of 0%, 20%,30%,40%,50%,60%,with constant proportion of glass fibre *i.e.*,by0.1% by volume of concrete. All the trial mixes are planned to be tested and then the optimum mix which gives the maximum strength criteria is to be found out.

Key words— self compacting concrete; copper slag; glass fibre; strength parameters;superplasticizer

1 INTRODUCTION

SCC is a new kind of High Performance Concrete (HPC) with excellent deformability and segregation resistance and can be considered as a concrete with high flow ability that can be placed and compacted under its own weight without any external vibration, assuring complete filling of formworks and also the complete covering of the reinforcing bars even when the space between the reinforcements is very narrow. Self-compacting concrete (SCC) was initially developed in Japan in the late 1980s as a concrete that can flow through overcrowded reinforcing bars with keeping out of external vibratory compaction, and without suffering any major segregation and bleeding. SCC is characterized by high flow ability in its fresh state and increased strength in its hardened state because of a compact matrix structure.

Due to its less tensile strength, concrete is subjected to crack on loading. Addition of fibres into concrete not only improves the overall ductility of the concrete imparting toughness, greater tensile strength, and resistance to fatigue, impact, blast loading and abrasion but also control the cracking, by the bridging of the fibres across the cracks, which delay the propagation and widening of localized cracks. Glass Fibre Reinforced Self-Compacting Concrete (GFRSCC) combines the advantages of SCC in its fresh state and that of fibres in its hardened state. .

2 LITERATURE REVIEW

V. Karthik et al (2015), in his work "Study On Durability Properties Of Self Compacting Concrete with Copper Slag Partially Replaced for Fine Aggregate" deal with the study on the workability and durability properties of SCC with copper slag partially replaced for fine aggregate and containing silica fume as mineral admixture.

Deepak Raj et al (2014), in the paper "Experimental Methods on Glass Fibres Reinforced Self Compaction Concrete" an attempt has been made to investigate the workability and mechanical properties of plain SCC and GFRSCC. With reference to the obtained test results we conclude that the addition of S-glass fibres does not affect the filling ability, passing ability and segregation resistance of the SCC.

Edwin Fernando et al(2014), in the study "Experimental Investigation of Self Compacting Concrete with Copper Slag" introduced a sequential method of adjusting the mix proportions by replacing part of the coarse aggregate with the fly ash has been shown to be suitable for obtaining SCC. Use of fly ash resulted in increase of 28 days compressive strength of concrete.

E. Sureshkumar et al (2013), in the work "Experimental Investigation of Self - Compacting Concrete using Copper Slag" examined the possibility of using copper slag as partial replacement of sand and Nano Silica as partial replacement of cement and super plasticizer and Viscosity Modifying Agent are used in self compacting concrete, in order to overcome problems associated with cast-in-place concrete.

D. Brindha et al (2010) in the report"Utilization of Copper Slag as a Partial Replacement of Fine Aggregate in Concrete"showed the potential use of granulated copper slag as a replacement for sand in concrete mixes. The effect of replacing fine aggregate by copper slag on the compressive strength and split tensile strength are attempted in this work. Addition of slag in concrete increases the density thereby the self weight of the concrete.

From above literatures, it can be summarised that copper slag can be used as substitute for fine aggregate and also glass fibre can be added to increase the compressive flexural and split tensile strength of concrete. But the combined use of copper slag and glass fibre was not covered in the literature. In this work, copper slag and glass fibre are used together in SCC along with mineral and chemical admixtures to improve the strength properties of concrete.

3 MATERIALS AND METHODOLOGY

3.1 cement

Cement is a binder substance that sets and hardens and can bind other materials together. Ordinary Portland cement (OPC) confirming to IS-12269-1987 (53 Grade) was used for the experimental work. The cement used has been tested as per IS 4031-1988to determine specific gravity, fineness, standard consistency, initial setting time, final setting time and compressive strength and found to be confirming to various specifications of IS 12269-1987.

Table 1 properties of cement

sl .no	property	test method	test results
1	Normal Consistency	Vicat Apparatus (IS: 4031 Part - 4)	30%
2	Specific gravity	Sp. Gravity bottle (IS:4031 Part - 4)	3.15
3	Initial setting time Final setting time	Vicat Apparatus (IS: 4031 Part - 4)	45 minutes 272 Minutes
4	Fineness	Sieve test IS: 4031 Part – 1)	4%

3.2 Fine Aggregate

The sand used for the experimental programmed was locally procured and conformed to grading zone II as per IS: 383-1970. The Fine aggregate used in this investigation was clean river sand passing through 4.75mm sieve with specific gravity of 2.63.

Table 2 Properties of Fine Aggregate

Sl. No	Particulars	Test Method	Values
1	Specific Gravity	Pycnometer (IS:2386 Part 3-1986)	2.63
2	Fineness modulus	Sieve Analysis (IS:2386 Part 2-1963)	3.2
3	Bulk density	IS:2386 Part 3-1986	1483kg/m³

3.3 Coarse aggregate

The aggregate of size 16 mm was considered as coarse aggregate. The coarse aggregate chosen for Self Compacting Concrete should be well graded and smaller in terms of the maximum size than that used for conventionally vibrated concrete. The rounded aggregates and smaller size of aggregate particles improves the flowability, deformability and segregate resistance of SCC.

Table 3 Properties of Coarse Aggregate

Sl. No	Particulars	Test Method	Values
1	Specific Gravity	Pycnometer (IS:2386 Part 3-1986)	2.66
2	Impact strength	IS:2386 Part 3-1986	9.41%
3	Crushing strength	Sieve Analysis (IS:2386 Part 2-1963)	21.57%

3.4 Copper Slag

Copper slag is a by-product created during the copper smelting and refining process. As refineries draw metal out of copper ore, they produce a large volume of non-metallic dust, soot, and rock. Collectively, these materials make up slag, which can be used for a surprising number of applications in the building and industrial fields

Comparison of Copper Slag with River Sand

- CuS behaves similar to river sand as it contains SiO2 similar to sand.
- Addition of CuS increases the density of concrete thereby increasing self weight.

The water absorption of CuS was measured to be 0.24% which is less than that of water (1.2%). Because of this CuS in concrete demand less water compared to sand in concrete mix

Table 4 Chemical Composition of Copper Slag

Component	% Content
Fe_2O_3	68.24
SiO_2	25.84
Al_2O_3	0.22
CaO	0.15
Na_2O	0.58
K_2O	0.23

Table 4.1 Physical Properties of Copper Slag

Physical Properties	Copper Slag
Particle Shape	Irregular
Appearance	Black
Type	Air Cooled
Specific Gravity	3.91
Fineness Modulus	3.47

3.5 Glass fibre

It is a material made from extremely fine fibres of glass. Fibre glass is a lightweight, extremely strong, and robust material. The glass fibre reinforcement results in a product with much higher flexural and tensile strengths than normal concrete, allowing its use in thin-wall casting applications.

Table 5 Chemical composition of Glass Fibre

Component	%content
SiO_2	64.2
Al_2O_3	24.8
CaO	0.01
B_2O_3	0.01
MgO	10.3
Na_2O	0.27
BaO	0.20
FeO	0.21

Table 5.1 Physical Properties of Glass Fibre

Sl. No	Property	Value
1	Specific Gravity	2.49
2	Tensile strength(MPa)	4590
3	Tensile modulus(GPa)	86
4	Diameter range (microns)	8-13
5	CTE (per million per C)	2.9

3.6 Mineral Admixtures

Mineral admixtures are added to concrete as a part of the cementitious material. To get better strength properties and good performance of SCC, it requires high quality of cementitious material, mineral admixtures like fly ash, silica fume, GGBFS etc.

3.6.1 Fly ash

Fly ash is one of the residues generated by coal combustion and is composed of the fine particles that are driven out of the boiler with the flue gases. Ash that falls in the bottom of the boiler is called bottom ash.

Table 6 Physical Properties of Fly Ash

properties	values
Specific gravity	2.69
Fineness modulus	3.43
Water absorption test	0.5%
Bulk Density test	1600 Kg/m^3

Table 6.1 Chemical Composition of Fly Ash

compounds	% content
SiO_2	45.98
Al_2O_3	23.55
Fe_2O_3	4.91
CaO	18.67
MgO	1.54
Na_2O	0.24
K_2O	1.80
SO_3	1.47

3.6.2 Ground Granulated Blast Furnace Slag (GGBS)

GGBS is used to make durable concrete structures in combination with ordinary portland cement and/or other pozzolanic materials. Two major uses of GGBS are in the production of quality-improved slag cement, namely Portland Blastfurnace cement (PBFC) and high-slag blast-furnace cement (HSBFC), with GGBS content ranging typically from 30 to 70%The GGBS used must be pure and fine.

Table 6.2 Physical and Chemical properties of GGBS

sl.no	characteristics	requirement as per bis: 6699	test result
1	Fineness (M / Kg)	275 (MIN)	390
2	Specific Gravity	-	2.85
3	Particle Size	45 MICRON	97.10
4	Insoluble Residue (%)	1.5 (Max)	0.49
5	Magnesia. Content (%)	14.0 (Max)	7.73

3.7 Super plasticizer

Super Plasticizer is used to increase the fluidity of the mix and improve the workability of concrete without adding more water. **Master Glenium 51** is poly carboxylic ether based high range water reducing new second generation super plasticizer concrete admixture

Table7 Properties of Glenium 51

TEST RESULTS	
Aspect	Light brown liquid
Relative density	1.08 @ 25^o
Ph	≥6
Density	1.082-1.042 kg/litre
Specific gravity	1.08

3.8 Mix Design

The study was limited to the preparation of five different types of mixes. One control mix and the remaining four mixes are prepared by replacing 20% to 60% fine aggregate by copper slag and 0.1% glass fibre (kept constant) by volume of concrete.Mix proportion of the proposed flowable concrete calculated using Nan Su. Method of mix design is obtained as:

C : A_F : A_C : FA : GGBS : W : SP = 1: 4.55 : 4.517 : 0.972 : 0.972 : 1.44 : 0.05

4 RESULTS AND DISCUSSION

4.1 slump cone test

The result of slump flow test carried for various percentages of copper slag is tabulated in table 4.1.1

Table 4.1.1 Slump flow test result

Copper Slag Percentage	Tested Values (mm)
Control Concrete (0%)	690
20%	720
30%	735
40%	742
50%	748
60%	735

The result obtained reveals that with an increase in percentage of copper slag upto 50%, the horizontal flowing ability of concrete increases and thereafter the flow decreases.

4.1.2 J-Ring test result

The result of J-Ring test carried out for various percentages of copper slag is tabulated in table 4.1.2.

Table 4.1.2 J-Ring test result

Copper Slag Percentage	**Difference in height inside & outside the ring (mm)**
Control Concrete (0%)	4.3
20%	3.8
30%	3.2
40%	2.4
50%	2.8
60%	3.7

The result obtained reveals that with an increase in percentage of copper slag upto 40%, the passing ability of concrete increases which is identified by a reduced difference in height between the concrete just inside the ring and the concrete just outside the ring. and above 40% of CuS, the difference in concrete just outside and inside the ring increases due to the obstructions.

4.1.3 V-Funnel test results

The result of V-Funnel test carried out for various percentages of copper slag is tabulated.
V-Funnel test denote the filling ability of the concrete. Initially the funnel is filled with about 12 litres of concrete without compacting or tamping simply by striking off and level the top of the concrete with trowel. Within ten seconds open the trap door and allow the concrete to fall and time taken for complete discharge of concrete is noted. The entire test has to be completed within 5 minutes. Flow time should be between 8-12 seconds.

Table 4.1.3 V-Funnel test results

Copper Slag Percentage	Time Taken (Sec)
Control Concrete (0%)	11
20%	11
30%	10
40%	9
50%	8
60%	6

The result obtained reveals that with an increase in percentage of copper slag, the time taken for the concrete to empty the V-Funnel reduces. Therefore it proves that a replacement of copper slag upto 50% can give a better filling ability of concrete.

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4.2 STRENGTH TESTS ON HARDENED CONCRETE

The results of the mechanical properties obtained based on the specimens tested as per Indian standard test procedures are discussed. M30grade of concrete, six different percentages of copper slag and two different ages of curing are the variables of investigation.

4.2.1Compressive Strength

Concrete cubes of size 150 mmx150mmx150mm were tested at 7th& 28th day and the values of compressive strength are given below.

The most common test performed on hardened concrete is compressive strength.Compressive strength of a material is defined as the value of uniaxial compressive stress reached when the material fails completely . Compressive strength increases on the addition of copper slag upto 40% and thereafter it is reduced. So it is clear from the graph that copper slag does not have any adverse effect on the compressive strength and also replacement upto 40% is beneficial.

Table 4.2.1 Compressive strength of M30 grade SCC

Mix Designation (Copper slag + glass fibre)	Compressive Strength(MPa)	
	7 days	28 days
CS0 (0%)	21.83	35.08
CS1 (20%+0.1%)	23.52	38.51
CS2 (30%+0.1%)	24.64	42.28
CS3 (40%+0.1%)	25.92	44.81
CS4 (50%+0.1%)	27.24	44.08
CS5 (60%+0.1%)	26.18	43.37

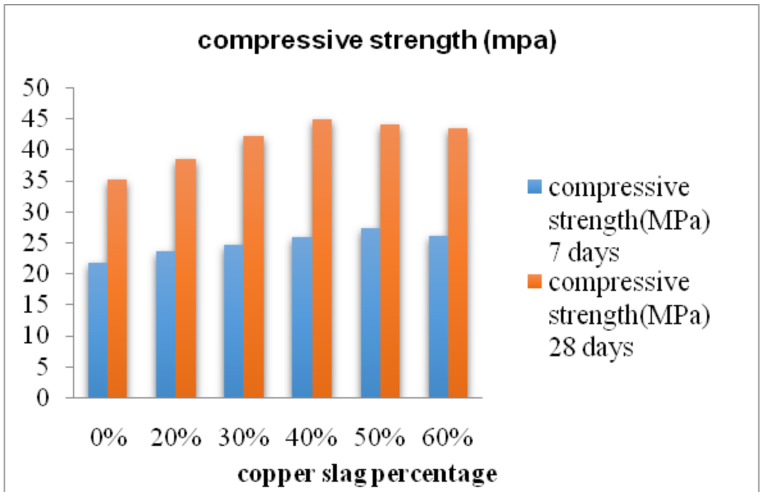

Figure 1 Compressive Strength @ 7th& 28th days

As the percentage of copper slag increases, compressive strength also increases. High toughness of Copper slag attributes to increased compressive strength. When copper slag percentage is greater 40, there is a reduction in the compressive strength. This is due to increased voids due to the fact that copper slag possesses fewer fine particles than fine aggregate. It could also be due to the increased free water content because the copper slag absorbs less water than the fine aggregate..

Table 4.2.2 Percentage Increase in Compressive Strength at 28th day

Mix Designation (Copper slag + glass fibre)	Avg compressive Strength (MPa)	Increase in Avg compressive strength w.r to Normal mix (%)
CS0 (0%)	35.08	-
CS1 (20%+0.1%)	38.51	9.77
CS2 (30%+0.1%)	42.28	20.52
CS3 (40%+0.1%)	44.81	27.73
CS4 (50%+0.1%)	44.08	25.65
CS5 (60%+0.1%)	43.37	23.63

As the percentage of by copper slag increases, compressive strength increases. Maximum percentage increase of 27.73% is obtained for glass fibre reinforced self compacting

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concrete with 40% replacement of fine aggregate by copper slag.

4.2 Split Tensile Strength

Concrete cylinders of 300 mm height and 150 mm diameter were tested at 7th and 28th day and the values of split tensile strength are given in Table 4.2.3

Split tensile strength increases on the addition of copper slag upto 50% and thereafter it is reduced. Addition of glass fibre also results in increased split tensile strength. So it is clear from the graph that copper slag does not have any adverse effect on the compressive strength and also replacement upto 50% is beneficial.

Table 4.2.3 Split tensile strength @ 7th& 28th day

Mix Designation (Copper slag + glass fibre)	Split tensile Strength	
	7 Days	28 Days
CS0 (0%)	1.92	3.17
CS1 (20% +0.1%)	2.07	3.25
CS2 (30%+0.1%)	2.24	3.73
CS3 (40%+0.1%)	2.58	4.09
CS4 (50%+0.1%)	3.05	4.62
CS5 (60%+0.1%)	2.98	4.23

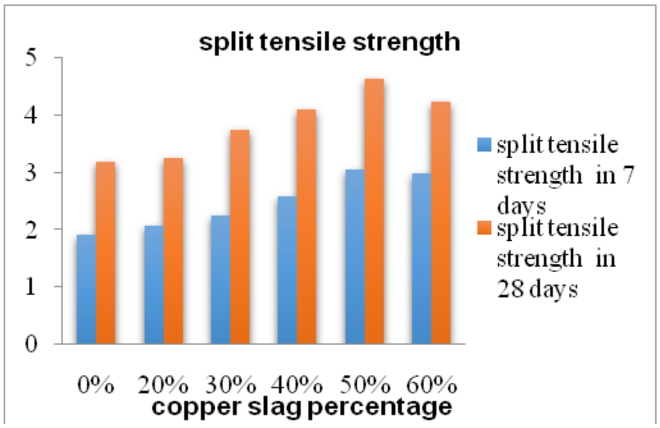

Figure 2 Split Tensile Strength @ 7th& 28th days

For all percentage replacement of fine aggregate by copper slag, the split tensile strength of concrete is more than control mix. Glass fibre across the splitting section is effective in resisting the splitting of cylinder.

Table 4.2.4 Percentage Increase in Split Tensile Strength at 28th day

Mix Designation (Copper slag + glass fibre)	Avg Split Tensile Strength (MPa)	Increase in avg Split Tensile strength w.r to Normal mix (%)
CS0 (0%)	3.17	-
CS1 (20% +0.1%)	3.25	2.52
CS2 (30%+0.1%)	3.73	17.66
CS3 (40%+0.1%)	4.09	29.02
CS4 (50%+0.1%)	4.62	45.74
CS5 (60%+0.1%)	4.23	33.43

Maximum increase in split tensile strength is 45.74 % which is obtained at 50% replacement of fine aggregate by copper slag.

4.3 Flexural Strength

Concrete beams of size 500 mm x 100 mm x 100 mm were tested at 28th day and the values of flexural strength

Table 4.2.5 Flexural strength @ 7th& 28th day

Mix Designation Copper slag + glass fibre	Flexural strength(MPa)	
	7 days	28 days
CS0 (0%)	1.61	3.65
CS1 (20% +0.1%)	2.43	3.88
CS2 (30%+0.1%)	2.5	4.29
CS3 (40%+0.1%)	2.8	4.83
CS4 (50%+0.1%)	3.24	5.23
CS5 (60%+0.1%)	2.92	5.04

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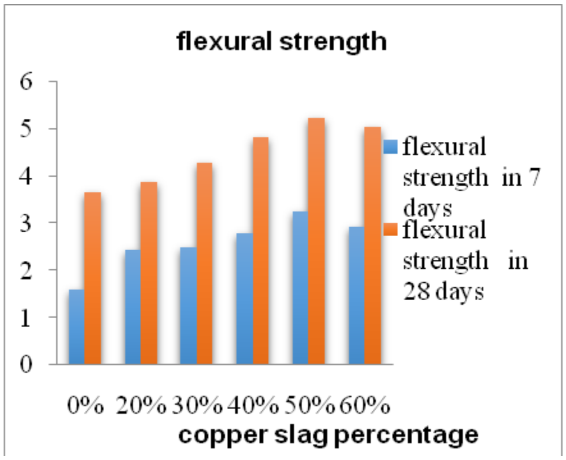

Figure 3flexural Strength @ 7th& 28th days

Flexural strength continued to increase with the increase in copper slag percentage at 7 and 28 days. Copper slag admixed self compacting concrete shows higher energy absorption values due to the addition of glass fibres. This is attributed to the ductile nature of copper slag admixed beams.

Table 4.2.6 Percentage Increase in Flexural Strength at 28th day

Mix Designation Copper slag + glass fibre	Avg:Flexural Strength (MPa)	Increase in avg:flexural strength w.r to Normal mix (%)
CS0 (0%)	3.65	-
CS1 (20% +0.1%)	3.88	0.82
CS2 (30%+0.1%)	4.29	17.53
CS3 (40%+0.1%)	4.83	32.32
CS4 (50%+0.1%)	5.23	43.28
CS5 (60%+0.1%)	5.04	38.08

Maximum percentage increase of 43.28% is obtained for glass fibre reinforced concrete with 50% replacement of fine aggregate by copper slag.

5 CONCLUSION

The main objective of present investigation was to experimentally study the mechanical properties of copper slag admixed glass fibre reinforced concrete. Experimental investigations were carried out to study the effect of glass fibre and copper slag on concrete. The mechanical properties such as compressive strength, flexural strength, split tensile strength were examined. The optimum mix in the view of strength consideration was found out.

The major conclusions drawn from this study are presented below:

- The strength parameters are optimum when the concrete containing 40% replacement of fine aggregate by copper slag in case of compressive strength and 50% replacement in case of split tensile strength and flexural strength.
- Due to low water absorption, coarser & glassy surface of copper slag, the workability of concrete increases when the % of copper slag increases.
- Compressive strength increases when the % of copper slag increases. High toughness of copper slag attributes to the increased compressive strength. Maximum percentage increase in compressive strength is 27.73 %. When copper slag % is greater 50%, there is a reduction in compressive strength. This is due to the increased voids and increased free water content.
- Flexural strength increases when the % of copper slag increases. Copper slag admixed concrete shows higher energy absorption values and this is attributed to the ductile nature of copper slag admixed beams. Maximum percentage increase in flexural strength is 43.28%.
- Split tensile strength increases when the % of copper slag increases. Glass fibre across the splitting section is effective in resisting the splitting of cylinder. Maximum percentage increase in split tensile strength is 45.74 %.
- The present investigation has brought out explicitly the effect of copper slag and glass fibre on the compressive strength split tensile strength and flexure strength of self-compacting concrete.

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