A Study on Glass Fiber Reinforced Self Compacting Concrete and Copper Fiber Reinforced Self Compacting Concrete - Comparison With Conventional Self Compacting Concrete

Sheik Sulthan Bee Bee[1], S Sivacharan[2]
[1]Dept of Civil Engineering
[2]Associate Professor, Department of Civil Engineering
[1, 2] Aditya College of Engineering and Technology

Abstract- *The aim of the present work is to make a comparative study on M30 grade self-compacting concrete by partial replacement of glass fiber and copper fiber reinforcement with conventional concrete.*

The variables involved in the study are type and different percentage of fibers. The basic properties of fresh SCC and mechanical properties, compression strength, Split Tensile Strength, Flexural Strength of hardened concrete were studied. The fibers used in the study are 12 mm long glass fiber and copper fiber. The volume fractions of fiber taken are 0%, 1%, 1.5%, 2%, and 2.5%. The project embraced two stages. The first stage consisted of the development of SCC mix design of M30 grade and in the second stage, different fibers like Glass and copper Fibers are added to the SCC mixes and their fresh and hardened properties were determined and compared.

The study showed significant enlargements in all properties of self-compacting concrete by adding fibers of different types and volume fractions. CFRSCC exhibited the best performance followed by GFRSCC in hardened state whereas poorest in the fresh state owing to its high water absorption. GFRSCC exhibited the best performance in a fresh state. The present study concludes that in terms of overall performances, optimum dosage and cost of fiber is the best option in improving the overall quality of self-compacting concrete

Keywords- Self-compacting concrete, Glass fibers, Copper fibers, compression strength, Split Tensile Strength, Flexural Strength.

I. INTRODUCTION

Fiber Reinforced Concrete can be defined as a composite material consisting of mixture of cement mortar or concrete and uniformly dispersed suitable fibres. Fibres include steel fibers, glass fibers, synthetic fibres and natural fibres. Fiber is a small piece of reinforcing material possessing certain characteristics properties. The fiber is often described by a convenient parameter called aspect ratio. The aspect ratio of the fiber is the ratio of its length to its diameter. Typical aspect ratio ranges from 30 to 150. Copper fibres are used as a fiber reinforcing material in concrete to study its effects on the compressive, crushing, flexural strength and cracking control.

The main purpose of the fiber is to control cracking and to increase the fracture toughness of the brittle matrix through bridging action during both micro and macro cracking of the matrix. Debonding, sliding and pulling-out of the fibers are the local mechanisms that control. the bridging action. In the beginning of macro cracking, bridging action of fibers prevents and controls the opening and growth of cracks. This mechanism increases the demand of energy for the crack to propagate. The linear elastic behavior of the matrix is not affected significantly for low volumetric fiber fractions.

At initial stage and the hardened state, Inclusion of fibers improves the properties of this special concrete. Considering it, researchers have focused on studied the strength and durability aspects of fiber reinforced SCC which are:

1. Glass fibers
2. Copper fibers

Fibers used in this investigation are of glass, copper, a brief report of these fibers is givenbelow.

OBJECTIVE

1. The objective of present research is to mix design of SCC of grade M30 and to investigate the effect of

inclusion of glass fiber & copper fiber on fresh properties and hardened properties of SCC.
2. Fresh properties comprise flow ability, passing ability, and viscosity related segregation resistance. Hardened properties to be studied are compressive strength, splitting tensile strength, flexural strength.
3. Fiber-reinforced self-compacting concrete uses the flow ability of concrete in fresh state to improve fiber orientation and in due course enhancing toughness and energy absorption capacity.
4. In the past few years there has been a boost in the development of concretes with different types of fibers added to it.
5. In the present work the mechanical properties of a self-compacting concrete with, glass & Copper fiber of length 12mm, added in various proportions (i.e., 0%, 0.5%, 1%, 1.5%, 2%, and 2.5%) will be studied in fresh and hardened state of fibered concrete was studied.
6. The present study is designed at M30 Grade FRSCC with Glass and copper fibres to know the mechanical properties, structural behavior and strength evaluation.

METHODOLOGY

Many researches has been done and ongoing on the fiber reinforced self compacting concrete by incorporating number of fibers, in this project an effort is composed to aid copper fiber and glass fibers in self compacting concrete to know the strength and durability of FRSCC.

1. To check the fresh and harden state properties of self compacting concrete which involves both glass fiber and copper fiber with appropriate proportions.
2. To check the fresh state properties i.e. Workability of this type of self compacting concrete where we will be knowing, how ease of working with concrete can be done i.e. Nothing but the slump of concrete.
3. In this study fiber percentage is varied so that we will come to know the optimum percentage of fiber which will give maximum strength of concrete.
4. Mix Design of self-compacting concrete of M30 grade, which high strength concrete can be achieved when this type of fibers is used.
5. Mixing of SCC and determination of its fresh properties in terms of flowability, passing ability and segregation resistance by using Slump flow, V-funnel and L-box apparatus.
6. Mixing of SCC impregnated with different fibers in different dosages and determination of their fresh properties in terms of flow-ability, passing ability and segregation resistance by using Slump flow, V-funnel and L-box apparatus.
7. Casting and testing of standard specimen to determine compressive, tensile, flexural strengths and incorporating glass fiber and copper fiber of different volume fraction ranging from 0.5% to 2.5% at 7 days, 14 days and 28 days.
8. To analyses the mechanical characteristics results at 7 days, 14 days and 28 days of casting and knowing % increase in strength from number of varying % of fibers, there by coming to know how much % strength has increased at standard curing.

II. LITERATURE REVIEW

1. **V.M.C.F. Cunha, et.al, (2011),** the author establishes numerical model for the ductile behavior of SFRSCC. They have presumed SFRSCC as two phase material. By 3-D smeared crack model, the nonlinear material behavior of self-compacting concrete is applied. The mathematical model presented good relationship with experimental values.
2. **C. A.M. Shende, et.al, (2012),** this paper concluded that It is detected that strength (compressive, flexural, split tensile) is on greater level for 3% fibers as related to that made by 0, 1 and 2%. Altogether the power features are detected to be on upper side for L/D of 50 as linked to 60 and 67. It is seen that compressive strength rises from 11 to 24%and flexural strength escalates from 12 to 49% and STS upsurges by 3 - 41% by way of surcharge of fibers.
3. **Mustapha Abdulhadi, et.al, (2012),** the author prepared M30 grade concrete and added polypropylene fiber 0% to 1.2% volume fraction by weight of cement and tested the compressive and split tensile strength and obtained the relation between them.
4. **M.G. Alberti, et.al, (2014),** in this paper the mechanical attributes of a self-compacting concrete with low, medium and high-fiber contents of macro polyolefin fibers are considered. Their fracture behavior is compared with a manifest self-compacting concrete and also with a steel fiber-reinforced self-compacting concrete.
5. **Chihuahua Jiang, et.al, (2014),** in this field, the effects of the volume fraction and length of basalt fiber (BF) on the mechanical properties of FRC were analyzed. The outcomes indicate that adding BF significantly improves the tensile strength, flexural strength and toughness index, whereas the compressive strength shows no obvious gain. Furthermore, the length of BF presents an influence on the mechanical properties.
6. **D. Syed Rahemath Peer Quadri, et.al, (2016),** In this venture we utilized the modern steel slag set up of common sand with expansion of steel fiber in bond

concrete for M30 review of cement. From this examination, we infer that, common waterway sand can be incompletely supplanted by steel slag up to 40% with 1.5% of steel fiber.

III. EXPERIMENTAL INVESTIGATION ON SCC

Wide spread applications of SCC have been restricted due to lack of standard mix design procedure and testing methods. It is pertinent to mention that only features of SCC have been included in Indian Standard Code of practice for plain and reinforced concrete (fourth revision), [2000]. Slump flow test, L-box test, V-funnel test, U-box test, Orimet test & GTM Screen test are recommended by EFNARC [European Federation of Producers and Applicators of Specialist Products for Structures, May 2005] for determining the properties of SCC in fresh state.

In this study, the mechanical behavior of fiber reinforced self-compacting concrete of M30 grade prepared with glass fiber and copper fiber were studied. For each mix six numbers of cubes (150×150×150) mm, three numbers of cylinders (150×300) mm and six numbers beams (100×100×500) mm were cast and investigations were conducted to study the mechanical behavior of plain Self Compacting Concrete (SCC), glass fiber reinforced Self Compacting Concrete (GFRSCC), copper fiber reinforced Self Compacting Concrete (CFRSCC).

The observational plan was held up in various steps to accomplish the following aims:

1. To prepare plain SCC of M30 grade and obtain its fresh and hardened properties.
2. To prepare glass & copper fiber reinforced SCC of M30 grades and studies their fresh and hardened properties.
3. To analyze the load-deflection behavior of SCC, GFRSCC & CFRSCC.
4. To examine the strength behavior of plain SCC, GFRSCC & CFRSCC.

Cement:

Physical characteristics of Ultra-Tech (53 Grade) cement used, tested in accordance with IS: 4031-1988 [Methods of physical tests for hydraulic cement].

Table: 3.1 Physical properties of Ordinary Portland Cement

S. No	Property	Test Method	Test Results	IS Standard
1.	Normal Consistency	Vicat Apparatus (IS:4031 Part-4)	28.5%	
2.	Specific Gravity	Sp. Gr Bottle (IS:4031 Part-4)	3.05	
3.	Initial Setting Time	Vicat Apparatus (IS:4031 Part-4)	86 minutes	Not less than 30 minutes
	Final Setting Time		510 Minutes	Not less than 10 hours
4.	Fineness	Sieve test on sieve no.9 (IS: 4031 Part -1)	4%	10%
5.	Soundness	Le-Chatlier method (IS: 4031 Part-3)	3mm	Not more than 10mm

Aggregates:

The aggregates must be proper shape, clean, hard, strong and well graded. The aggregate which is retained over IS Sieve 4.75 mm is termed as coarse aggregate. The normal maximum size is gradually 10-20 mm. The aggregates most of which pass through 4.75 mm IS sieve are termed as fine aggregates. According to size, the fine aggregate may be described as coarse, medium and fine sands. Depending upon the particle size distribution IS: 383-1970 has divided the fine aggregate into four grading zones (Grade I to IV). The grading zones become progressively finer from grading zone I to IV.

Table: 3.2 Physical properties of Coarse and Fine aggregate.

S. No	Property	Method	Fine Aggregates	Coarse Aggregates
1.	Specific Gravity	Pycnometer IS:2386 Part3-1986	2.65	2.85
2.	Bulk Density Loose Compacted	IS:2386 Part 3-1986	1428 kg/m^3 1580 kg/m^3	1651kg/m^3 1896kg/m^3
3.	Bulking	IS:2386 Part 3-1986	10% water	---
4.	Flakiness Index	(IS:2386 Part 2-1963)	---	8.08%
5.	Elongation Index	(IS:2386 Part 2-1963)	---	0%
6.	Fineness Modulus	Sieve Analysis (IS:2386 Part 2-1963)	3.18	6.04

Water:

The potable water is generally considered satisfactory for mixing and curing of concrete. Accordingly potable water was used for making concrete available in Material Testing laboratory. This was free from any detrimental contaminants and was good potable quality.

Admixtures &Super plasticizers:

The most important admixtures are the Super plasticizers (high range water reducers), used with a water reduction greater than 20%. The use of a Viscosity modifying Admixture (VMA) gives more possible of controlling segregation when the amount of powder is limited. This admixture helps to provide very good homogeneity and reduces the tendency to segregation. The **Sika ViscoCrete Premier** from Sika is super plasticizer and viscosity modifying admixture, used in the present study.

High-range water reducer, also known as super plasticizer, has made a breakthrough in concrete industry. It is an essential material component that must be used to produce SCC. The HRWRs improve the flowing ability of SCC by their liquefying and dispersing actions. They reduce the yield stress and plastic viscosity of concrete by their liquefying action and thus provide a good flowing ability in SCC.

The Viscosity modifying agent (VMA) used in this investigation was **Glenium stream-2** which is a product of BASF construction chemicals.

Table: 3.3 Physical requirements of Super Plasticizer

S.No	Characteristics	Test value
1.	Chloride content	Nil
2.	Specific Gravity	1.26 at 30°C
3.	Solid content	40 %
4.	Nature Liquid	---

Table: 3.4 Details of Viscosity Modifying Agent

S.No	Property	Result
1.	Aspect	Colourless free flowing liquid
2.	Relative density	1.01
3.	PH	≥ 6.5
4.	Chloride ion content	< 0.2%
5.	Compatibility	Can be used with all types of cements
6.	Incompatible	Use with naphthalene sulphonate based super plasticiser admixtures.
7.	Mechanism of action	It consists of a mixture of water soluble copolymers which is adsorbed onto the surface of the cement granules, thereby changing the viscosity of the water and influencing the rheological properties of the mix.
8.	Dosage	50 to 500 ml/100 kg of cementitious material.

ALKALI RESISTANT GLASS FIBERS

Glass fibers come in two forms (1) Continuous fibers (2) Discontinuous or chopped fibers Principal advantages are low cost, high strength, easy and safe handling, and rapid and uniform dispersion facilitating homogeneous mixes which in term produce durable concrete. Limitations are poor abrasion resistance causing reduced usable strength, Poor adhesion to specific polymer matrix materials, and Poor adhesion in humid environments.

Alkali Resistant Glass Fibers

Table: 3.5 Physical and mechanical properties of alkali resistant glass fiber.

S.NO	Property	Value
1.	Virgin fiber tensile strength	3500MPa
2.	Industrial strand tensile strength	1700MPa
3.	Modulus of elasticity	43 GPa
4.	Fiber length (l_f)	12mm
5.	Fiber diameter (d_f)	14 (microns)
6.	Aspect ratio (λ=lf/df)	857
7.	Density	2.53 (g/cm^3)
8.	Elongation at breaking point	7-9%
9.	Specific gravity	2.68
10.	Strain at failure	2.4%
11.	Softening temperature	860°C
12.	Water absorption	<0.1%

COPPER FIBER

For the present investigation, waste electrical copper wire was used as a fiber with a cut length of 12mm and its properties are as follows:

1. It gives greater confrontation to load and can survive without breaking or deformation under tensile stresses.
2. It offers higher strength without crushing the metallic bond called ductility property.
3. Creep confrontation: it gives steady buckling of concrete from expansion and contraction under load or no load pattern of condition.
4. Copper fibers are used as a reinforcing material in self compacting concrete for following reasons like Corrosion resistant, Antibacterial, Easily joined, Ductile, Tough, Nonmagnetic, Attractive colour and Alloys easily.
5. Rusting opposition: It offers confrontation to rusting action
6. Length= 12mm and least lateral dimension= 14microns.

Copper fiber

Copper fiber used in this investigation was procured from Mayuri Fiber Industry: D/No. 45-6-2, Jagannayakpur, Kakinada-533002, Andhra Pradesh, India.

Table: 3.6 Physical and mechanical properties of copper fiber.

S.NO	Property	Value
1.	Virgin fiber tensile strength	5200MPa
2.	Industrial strand tensile strength	4800MPa
3.	Modulus of elasticity	93 GPa
4.	Fiber length (l_f)	12mm
5.	Fiber diameter (d_f)	14 (microns)
6.	Aspect ratio (λ=lf/df)	857
7.	Density	2.65 (g/cm^3)
8.	Elongation at breaking point	3.2%
9.	Specific gravity	2.46
10.	Strain at failure	1.6%
11.	Softening temperature	920°C
12.	Water absorption	<0.5%

MIX PROPORTIONING

In designing the SCC mix, it is most useful to consider the relative proportions of the key components by volume rather than by mass. The following key proportions for the mixes listed below:

Table: 3.7 Adopted Mix Proportions of SCC

Cement (kg/m^3)	Water (kg/m^3)	FA (kg/m^3)	CA (kg/m^3)	SP (kg/m^3)
510	193.8	672	778	4.98
1	0.38	1.31	1.52	0.018

The mix proportioning was done based on the Nan Su approach [2001]. The Mix Design types with percentage relative proportions and mix proportions of constituent materials are given in the table form.

Grade	Mix	W/B	Water (Kg/m^3)	Cement (Kg/m^3)	Glass & Copper Fiber (%)	GFRSCC (Kg/m^3)	CFRSCC (Kg/m^3)	FA (Kg/m^3)	CA (Kg/m^3)	SP (%)
M30	Trial -1	0.38	193.8	510	0	0	0	672	778	0.018
	Trial -2			512	1	5.12	5.12	672	778	0.018
	Trial -3			510	1.5	7.65	7.65	672	778	0.018
	Trial -4			511	2	10.22	10.22	672	778	0.018
	Trial -5			513	2.5	12.82	12.82	672	778	0.018

IV. EXPERIMENTAL RESULTS ON GFRSCC & CFRSCC

The first stage of investigations was carried out to develop SCC mix of a minimum strength M30 grade using chemical admixtures and super plasticizers, and to study its fresh and hardened properties. For developing SCC of strength M30 grade, the mix was designed based on EFNARC 2005 code using mineral admixture. Finally, SCC mixes which yielded satisfactory fresh properties and required compressive strength, were selected and taken for further investigation. In the second stage of investigation SCC with different fiber contents with different volume fraction were mixed.

Water/cement Ratio of Self-Compacting Concrete:

To maintain the basic characteristics of self-compacting concrete a water cement ratio of 0.42 was adopted and a % dosage of super-plasticizer Viscocrete of Sika brand were fixed for all mixes.

Mix Proportions and Fiber Content:

The number of trial mixes was prepared in the laboratory and satisfying the requirements for the fresh state given by EFNARC 2005 code. The present work involved preparation of M30 grade SCC and to study its behavior when different types of fibers were added to it. Plain SCC of M30 grade was prepared using silica fume as mineral admixture with sikaviscocrete as admixture.

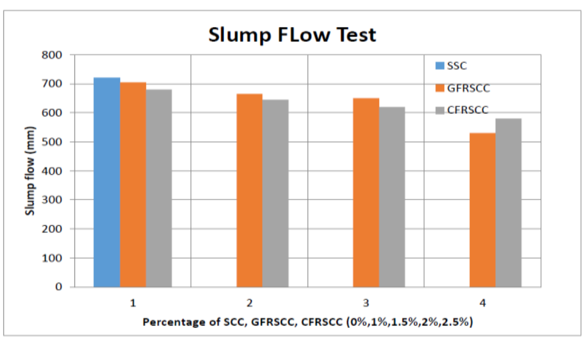
DESIGNATION	FIBRES CONTENT (%)	DESCRIPTION
SSC	0.0%	Plain self-compacting concrete
GFRSCC-1	1%	1% Glass fiber reinforced SCC
GFRSCC -1.5	1.5%	1.5% Glass fiber reinforced SCC
GFRSCC -2	2%	2% Glass fiber reinforced SCC
GFRSCC -2.5	2.5%	2.5% Glass fiber reinforced SCC
CFRSCC-1	1%	1% Copper fiber reinforced SCC
CFRSCC -1.5	1.5%	1.5% Copper fiber reinforced SCC
CFRSCC -2	2%	2% Copper fiber reinforced SCC
CFRSCC -2.5	2.5%	2.5% Copper fiber reinforced SCC

Results and Discussion about Fresh Properties:

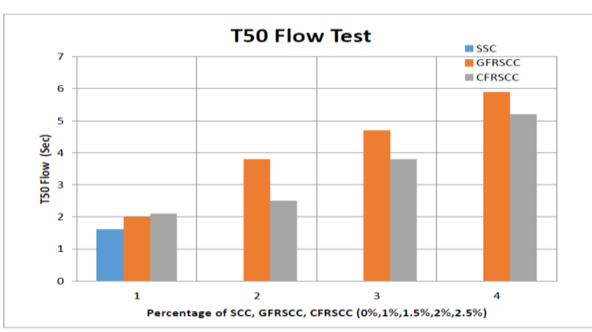
Table 4.2.1 Results of the Fresh Properties of Mixes

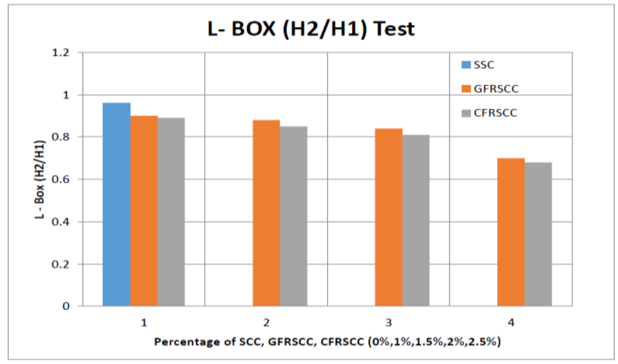
sample	Slump flow 500-750mm	T_{50} flow 2-5sec	L-Box(H_2/H_1) 0.8-1.0	V-Funnel 6-12sec	T5 Flow +3sec	Remarks
SSC	720	1.6	0.96	5	9	Low viscosity (Result Satisfied)
GFRSCC-1	705	2.0	0.90	7	10	Result Satisfied
GFRSCC-1.5	665	3.8	0.88	7.7	11	Result Satisfied
GFRSCC-2	650	4.7	0.84	8.5	12	Result Satisfied
GFRSCC-2.5	530	5.9	0.70	11	15	Too high viscosity Blockage (Result Not Satisfied)
CFRSCC-1	680	2.1	0.89	8	12	Result Satisfied
CFRSCC-1.5	645	2.5	0.85	8	13	Result Satisfied
CFRSCC-2	620	3.8	0.81	9	14	Result Satisfied
CFRSCC-2.5	580	5.2	0.68	10	16	High viscosity Blockage (RNS)

Graph 4.2.1 Slump flow test for SCC, GFRSCC, and CFRSCC

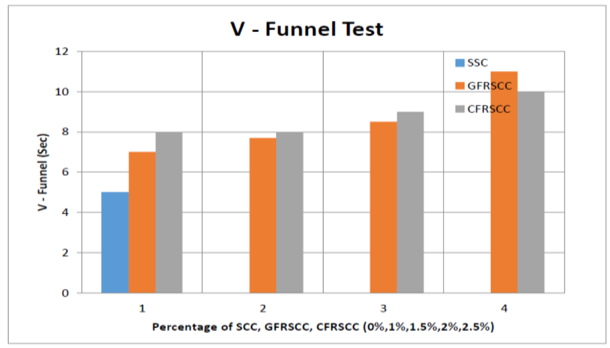


Graph 4.2.2 T50 flow test for SCC, GFRSCC, and CFRSCC





Graph 4.2.4 V - Funnel test for SCC, GFRSCC, and CFRSCC



Slump Flow

The slump flow decreases with increase in fiber percentage. The decrease in flow value is observed maximum 27.77 % for copper fiber 26.38% for glass fiber and w.r.t control mix. This is because copper fibers absorbed more water from the mix and beyond 2% fiber addition the mix did not satisfied the norms of self-compacting concrete. Glass fibers absorb lowest water.

T50 Flow

The T50 flow, which was measured in terms of time (seconds) increases as the slump flow value decreases. The decrease in slump value is due to the increase in the percentage of fiber which was explained in previous section. The maximum time taken to flow was observed at 2% for glass fiber and 2.5% for copper fiber.

L-Box

The L-Box value increases as the slump flow value increases. The increase in slump value is due to the increase in the percentage of fiber as well as the L-Box value also increases. The maximum value obtained in the case of control mix but as per SCC specification 2% copper fiber and 2.5% glass fiber fulfill the requirements.

V-Funnel & T5 flow

The V-Funnel test & T5 flow, which was measured in terms of time (seconds) & both the value measured are dependent with each other. V-Funnel value and T5 flow increases as the slump flow value decreases. The decrease in slump value is due to the increase in the percentage of fiber. It was observed that at 2% of copper fiber and 2.5% of glass fiber the SCC specification were satisfied.

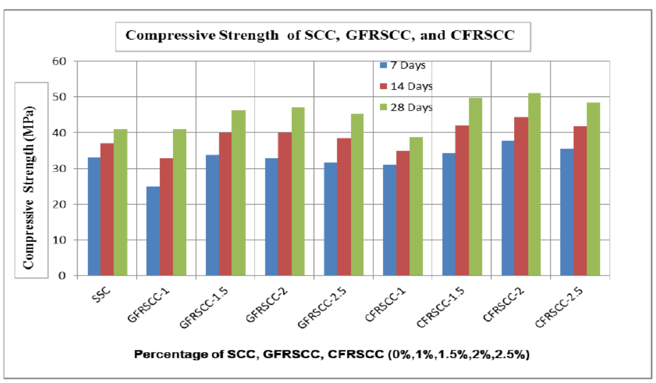
Hardened Properties:

To compare the various mechanical properties of the SCC, GFRSCC, and CFRSCC mixes the standard specimens were tested after 7 days, 14 days, and 28 days of curing. The results are summarized in below tables.

Table- 4.3.1 Compressive Strength of SCC, GFRSCC, and CFRSCC (7, 14, & 28Days)

Compressive strength (MPa)				
S.No	Mix	7 Days	14 Days	28 Days
1.	SSC	33.185	37.0375	40.89
2.	GFRSCC-1	24.88	32.885	40.89
3.	GFRSCC-1.5	33.77	40	47.11
4.	GFRSCC-2	32.89	38.98	46.19
5.	GFRSCC-2.5	31.55	38.44	45.33
6.	CFRSCC-1	31.11	34.89	38.67
7.	CFRSCC-1.5	34.22	41.995	49.77
8.	CFRSCC-2	37.77	44.38	50.99
9.	CFRSCC-2.5	35.48	41.9	48.32

Graph- 4.3.1 Compressive Strength of SCC, GFRSCC, and CFRSCC



Compressive Strength:

7-Days Compressive Strength

Compared to the plain SCC the compressive strength reinforced with copper fiber of volume fraction 1.5%, and 2% increase by 3.12%, and 13.82% respectively. Compared with the plain SCC the compressive strength reinforced with glass fiber of volume fraction 1.5% increase by 1.76%. In this study the 7 days compressive strength of glass fiber shows no obvious improvement. Compared with the plain SCC the compressive strength reinforced with copper fiber of 1.5% and 2% increase by 29.9% and 23.22% respectively. The graph shows that for GFRSCC and CFRSCC has higher compressive strength at 7 days at volume fraction of 1.5%.

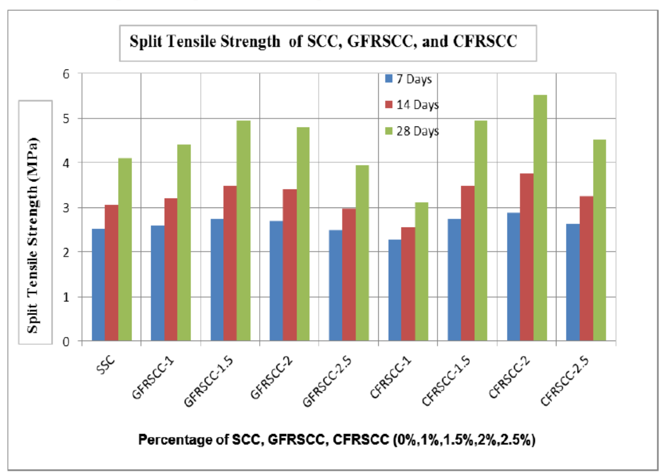
28-Days Compressive Strength

Compared with plain SCC, 1.5% of GFRSCC and CFRSCC increase 10.52% and 47.6% respectively. For 2% and 2.5% of GFRSCC decrease 15.21% and 35% respectively. For 2% of CFRSCC increase 24.7% and 32% respectively. For 2.5% of CFRSCC decreases 40.16% respectively. In this study, that the optimum dosages for GFRSCC are 1.5%, and for CFRSCC is 2.0%.

Table- 4.3.2 Split Tensile Strength of SCC, GFRSCC, and CFRSCC (7, 14, & 28Days)

Split Tensile strength (MPa)				
S.No	Mix	7 Days	14 Days	28 Days
1.	SSC	2.53	3.05	4.10
2.	GFRSCC-1	2.61	3.21	4.42
3.	GFRSCC-1.5	2.74	3.48	4.95
4.	GFRSCC-2	2.70	3.41	4.81
5.	GFRSCC-2.5	2.49	2.98	3.96
6.	CFRSCC-1	2.28	2.56	3.11
7.	CFRSCC-1.5	2.74	3.48	4.95
8.	CFRSCC-2	2.88	3.76	5.52
9.	CFRSCC-2.5	2.63	3.26	4.52

Graph- 4.3.2 Split Tensile Strength of SCC, GFRSCC, and CFRSCC



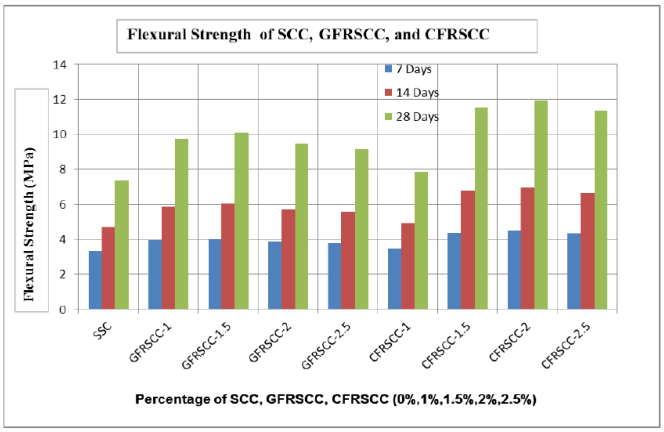
Split Tensile Strength:

The percentage enhancement of split tensile strength for copper fiber over plain SCC is 20.44%, 34.56%, and 10.24% when adding 1.5%, 2%, and 2.5% respectively. The percentage enhancement of split tensile strength for glass fiber over plain SCC is 20.31%, 17.73% when adding 1.5% &2% respectively. The increase is due to the fiber as explained before. In this study, that the optimum dosages for GFRSCC are 1.5%, and for CFRSCC is 20%.

Table- 4.3.3 Flexural Strength of SCC, GFRSCC, and CFRSCC (7, 14, & 28Days)

Flexural strength (MPa)				
S.No	Mix	7 Days	14 Days	28 Days
1.	SSC	3.34	4.69	7.37
2.	GFRSCC-1	3.94	5.87	9.74
3.	GFRSCC-1.5	4.02	6.04	10.08
4.	GFRSCC-2	3.87	5.73	9.46
5.	GFRSCC-2.5	3.79	5.58	9.15
6.	CFRSCC-1	3.46	4.92	7.84
7.	CFRSCC-1.5	4.38	6.76	11.52
8.	CFRSCC-2	4.48	6.96	11.92
9.	CFRSCC-2.5	4.34	6.67	11.34

Table- 4.3.3 Flexural Strength of SCC, GFRSCC, and CFRSCC



Flexural Strength:

The Above Table and Graph shows flexural strengths of GFRSCC & CFRSCC mixes after 28 days. The graph 4.3.3 shows the optimum fiber fraction imparting maximum flexural strength with different fibers. As expected, all GFRSCC & CFRSCC specimens show an increase in flexural strength with increase in fiber content. Compared with the plain SCC the enhanced percentages of the flexural strength of GFRSCC were observed in the range of 2.03% to 67.16% while 0.15% gave maximum strength. Increases in flexural strength were observed in ranges from 0.95% to 36.77% for CFRSCC with the fiber percentage of 1% to 2%. Maximum flexural strength 11.92 MPa was observed for CFRSCC for 2% of fiber percentage. In this study, that the optimum dosages for GFRSCC are 1.5%, and for CFRSCC is 2.0%.

V. CONCLUSIONS

From the present study the following conclusions can be drawn.

1. Addition of fibers to self-compacting concrete causes loss of basic characteristics of SCC measured in terms of slump flow, etc.
2. Reduction in slump flow was observed maximum with copper fiber, then glass fiber respectively. This is because copper fibers absorbed more water than others and glass absorbed less.
3. Copper fiber addition more than 2% made mix harsh which did not satisfy the aspects like slump value, T50 test etc. required for self-compacting concrete.
4. Addition of fibers to self-compacting concrete improve mechanical properties like compressive strength ,split tensile strength, flexural strength etc. of the mix.
5. There was an optimum percentage of each type of fiber, provided maximum improvement in mechanical properties of SCC.
6. Mix having 1.5% glass fiber, and 2.0% of copper fiber were observed to increase the mechanical properties to maximum.
7. 1.5% addition of glass fiber to SCC was observed to increase the 7-days compressive strength by 29.9%, 28-days compressive strength by 47.6%, split tensile strength by 56.24%, flexural strength by 67.16%.
8. 2% addition of copper fiber to SCC was observed to increase the 7-days compressive strength by 37.05%, 28-days compressive strength by 50.16%, split tensile strength by 59.24%, flexural strength by 70.73%.
9. The performance of copper fiber reinforced SCC mixes was better than glass FRSCC mixes. Then copper fiber FRSCC exhibited best mechanical properties with comparatively lower volume fraction but its effect on SCC fresh properties was just reverse. Its inclusion reduced flow-ability, deformability because it absorbs more water.
10. Copper FRSCC exhibited better properties in fresh state and hardened state compared to the Glass FRSCC. In terms of the cost it is cheaper than glass fiber hence copper fiber performance is overall best compared with glass fiber.

REFERENCES

[1] Ouchi M. and Okamura H. "Mix-Design for Self-Compacting Concrete", Concrete Library of JSCE, No.25, June 1995(ND), pp107-120.

[2] Ouchi M. and Okamura H. “Effect of Super plasticizer On Fresh Concrete”, Journal of Transportation Board, 1997, pp37-40.

[3] Khayat. K.H. "Workability, Testing and Performance of Self-consolidating Concrete" Technical Paper Title No. 96-M43, ACI Journal/May-June 1999, pp346-353.

[4] Victor C. Li, H.J.Kong, and Yin-Wen Chan "Development of Self-Compacting Engineered

Cementitious Composites" The University of Michigan, Ann Arbor-MI 48109-2125, USA,(1999).
[5] Gaopeiwei, Deng Min and FengNaiqui "The Influence of SP and Superfine Mineral Powder on the Flexibility, Strength and Durability of HPC". Cement and Concrete Research. 2000, vol.31, pp703-706.
[6] Neol P Mailvaganam. "How Chemical Admixtures Produce their Effects in Concrete", Indian Concrete Journal, May 2001, pp331- 334.
[7] Nan Su, Kung-Chung Hsu, His-Wen Chai "A Simple Mix Design method for Self-Compacting Concrete" Journal of Cement and Concrete Research 31(2001), pp1799-1807.
[8] Sonebi. M and Bartos. P. J. M "Filling ability and Plastic Settlement of Self Compacting Concrete" Materials and Structures, Vol.35 September-October 2002 pp462-469.
[9] IS: 456 - 2000 Code of practice for plain and reinforced concrete (fourth revision).
[10] IS: 516 - 1959 Method of test for strength of concrete (sixth print January, 1976).
[11] IS: 12269-1987 Specifications for 53 Grade Ordinary Portland cement.
[12] IS: 383- 1970 Specification for Coarse and fine aggregates from natural sources for concrete.
[13] IS: 2386 - 1963 (all parts) Methods of test for aggregate for concrete.
[14] "Properties of Concrete", by Neville. A. M. - Longman, Pearson Education Asia Pte. Ltd, Fourth Edition, First Indian reprint 2000.
[15] "Design of Concrete Mixes", by N. Krishna Raju, CBS Publishers &Distributors, Delhi, 1993.
[16] "Concrete Technology - theory and practice", by M. S. Shetty, S. Chand Company Ltd, Delhi, First multicolor illustrative revised edition, reprint 2008.
[17] "Concrete Technology" by A R Santhakumar, Oxford university press, Delhi, first published 2007.