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STUDY ON MECHANICAL PROPERTIES AND FRACTURE BEHAVIOR OF CHOPPED GLASS FIBER REINFORCED SELF-COMPACTING CONCRETE

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ABSTRACT
The growth of Self Compacting Concrete is revolutionary landmark in the history of construction industry resulting in predominant usage of SCC worldwide nowadays. It has many advantages over normal concrete in terms of enhancement in productivity, reduction in labour and overall cost, excellent finished product with excellent mechanical response and durability. Incorporation of fibres further enhances its properties specially related to post crack behavior of SCC. Hence the aim of the present work is to make a comparative study of mechanical properties of self consolidating concrete, reinforced with glass fibres. The variables involve in the study are type and different percentage of fibres. The basic properties of fresh SCC and mechanical properties, toughness, fracture energy were studied. Microstructure study of various mixes is done through scanning electron microscope to study the hydrated structure and bond development between fiber and mix. The primary aim of this study is to explore the acceptability of demolished concrete waste aggregate to make self compacting concrete of high strength and desirable properties. The compressive strength of all the concrete mixes were measured at the age of 7 and 28 days, and testing them for, water absorption, sulfate resistance.

KEYWORDS: SCC, Fibers, Mechanical properties.

INTRODUCTION
Making concrete structures without vibration have been done in the past. For examples, placement of concrete under water is done by the use of termite without vibration. Mass concrete, and shaft concrete can be successfully placed without vibration. But the above examples of concrete are generally of lower strength and difficult to obtain consistent quality. Modern application of self-compacting concrete (SCC) is focussed on high performance, better and more reliable and uniform quality. Self-compacting concrete, in principle, is not new. Early self-compacting concretes relied on very high contents of cement paste and, once super plasticizers became available, they were added in the concrete mixes. The mixes required specialized and well-controlled placing methods in order to avoid segregation, and the high contents of cement paste made them prone to shrinkage. The overall costs were very high and applications remained very limited.

Self-compacting concrete has been described as “the most revolutionary development in concrete construction for several decades”. Originally developed in Japan to offset a growing shortage of skilled labour, it has proved to be beneficial from the following points,

1. Faster construction,
2. Improved durability,
3. Reduction in site manpower,
4. Better surface finish
5. Easier placing,
6. Safer working environment.

Usually, the chemical admixtures used are high-range water reducers (super plasticizers). Mineral admixtures are used as an extra fine material, besides cement, and in some cases, they replace cement.

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OBJECTIVE AND METHODOLOGY

The objective of present research is to mix design of SCC of grade M30 and to investigate the effect of inclusion of chopped basalt fiber, glass fiber & carbon fiber on fresh properties and hardened properties of SCC. 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, modulus of elasticity, Ultrasonic pulse velocity and fracture energy. 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.

In the present work the mechanical properties of a self compacting concrete with chopped Basalt, glass & Carbon fiber of length 12mm, added in various proportions (i.e., 0%, 0.1%, 0.15%, 0.2%, 0.25%, 0.3%) will be studied in fresh and hardened state. With the help of scanning electron microscope (SEM) the microstructure of fibered concrete was also studied.The fracture energy behavior is one parameter that is very useful in calculating the specific fracture energy, GF, is by means of a uniaxial tensile test, where the complete stress-deformation curve is measured.

Fiber Reinforced Self-Compacting Concrete

There is an innovative change in the Concrete technology in the recent past with the accessibility of various grades of cements and mineral admixtures. However there is a remarkable development, some complications quiet remained. These problems can be considered as drawbacks for this cementations material, when it is compared to materials like steel. Concrete, which is a „quasi-fragile material‟, having negligible tensile strength? Several studies have shown that fiber reinforced composites are more efficient than other types of composites. 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. Deboning, 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. Carbon fibers
3. Basalt fibers
4. Polypropylene fibers etc.

EXPERIMENTAL INVESTIGATION ON SELF-COMPACTING CONCRETE

In this study, the mechanical behavior of fiber reinforced self-compacting concrete of M30 grade prepared with basalt fiber, glass fiber and carbon fiber were studied. For each mix six numbers of cubes (150×150×150) mm, three numbers of cylinders (150×300) mm and six numbers prisms (100×100×500) mm were cast and investigations were conducted to study the mechanical behavior, fracture energy behavior, microstructure of plain SCC glass fiber reinforced SCC (GFC), carbon. 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 basalt, glass & carbon fiber reinforced SCC of M30 grades and study their fresh and hardened properties.
3. To analyze the load-deflection behavior of SCC, GFRSCC.
4. To examine the fracture energy behavior & the micro structure of plain SCC, GFC

MATERIALS

Cement

Portland slag cement of nagarjuna brand available in the local market was used in the present studies. The physical properties of PSC obtained from the experimental investigation were confirmed to IS: 455-1989.

Coarse Aggregate

The coarse aggregate used were 20 mm and 10 mm down size and collected from near by query.

Fine Aggregate

Natural river sand has been collected from Krishna River, and conforming to the Zone-III as per IS-383-1970.

Silica Fume

Elkem Micro Silica 920D is used as Silica fume. Silica fume is among one of the most recent pozzolanic materials currently used in concrete whose addition to concrete mixtures results in lower porosity, permeability and bleeding because its fineness and pozzolanic reaction Admixture

The SikaViscoCrete Premier from Sika is super plasticizer and viscosity modifying admixture, used in the present study.

Water

Potable water conforming to IS: 3025-1986 part 22 &23 and IS 456-2000 was employed in the investigations.

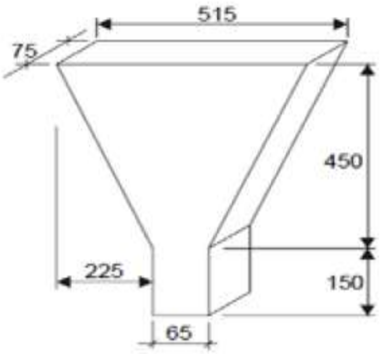
Glass Fiber

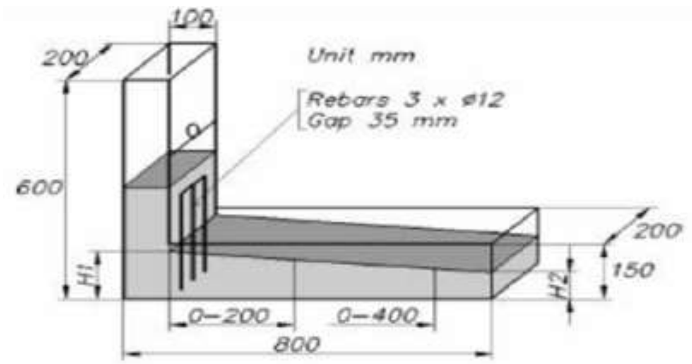
Alkali resistant glass fiber having a modulus of elasticity of 72 GPA and 12mm length was used.

Table :1 shows the properties of the of fibers.

Fiber variety	Length mm	Density (g/cm^3)	Elastic Modulus(GPa)	Tensile Strength(MPa)	Elong .at Break(%)	Water absorption
GLASS	12	2.53	43-50	1950-2050	7-9	<0.1

Testing procedures





V-Funnel Test ***L-Box Test***

Casting of Specimens

Eighty four numbers cubes(150×150×150)mm, forty two numbers cylinders(150×300)mm, eighty-four numbers prisms(100×100×500)mm were casted and investigations were conducted to study the mechanical behavior, fracture behavior, microstructure of plain SCC, glass fiber reinforced SCC(GFC).

Curing Of SCC Specimens

After casting was done the cubes were kept in room temp. For 24 hours then the moulds were removed and taken to the curing tank containing fresh potable water to cure the specimen for 7 days and 28days.

Testing Of Hardened SCC

A proper time schedule for testing of hardened SCC specimens was maintained in order to ensure proper testing on the due date. The specimens were tested using standard testing procedures as per IS: 516-1959.

Testing blocks before testing

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RESULTS AND DISCUSSIONS

Description of mixes for M30

S.No.	Designation	Fibre content(%)	Description
1	PSC	0.0%	Plain compacting concrete
2	GFC-1	0.1	0.1%glass fiber added to SCC
3	GFC-1.5	0.15	0.1%glass fiber added to SCC
4	GFC-2.0	0.2	0.1%glass fiber added to SCC
5	GFC-2.5	0.25	0.1%glass fiber added to SCC
6	GFC-3	0.3	0.1%glass fiber added to SCC

Results

Sample	Slump flow 500-750mm	T_{50}flow 2-5sec	L-box (H_2/H_1)0.8-1.0	V-funnel 6-12 sec	T5flow +3sec	Remarks
PSC	720	1.6	0.96	5	9	Low viscosity Result satisfied
GFC-1	710	1.9	0.90	7	10	Result satisfied
GFC-1.5	670	3.75	0.87	7.6	11	Result satisfied
GFC-2.0	655	4.6	0.83	8.4	12	Result satisfied
GFC-2.5	640	5.0	0.80	9.1	12	Result satisfied
GFC-3	630	5.8	0.71	11	15	Too high viscosity Blockage

Hardened Properties

To compare the various mechanical properties of the FRSCC mixes the standard specimens were tested after 7 days and 28 day of curing. The results are summarized in Table

S.No.	Mixes	7-days compressive strength(MPa)	28-days compressive strength(MPa)	28days split tensile strength(MPa)	28-day flexural strength(MPa)
1	PSC	33.185	40.89	4.1	7.37
2	GFC-1	24.86	40.88	2.98	7.44
3	GFC-1.5	33.68	46.21	4.80	9.72
4	GFC-2.0	32.72	47.18	4.95	10.02
5	GFC-2.5	31.49	45.33	3.94	9.4
6	GFC-3	23.74	39.2	3.67	8.28

Description of mixes for M40

S.No.	Designation	Fiber content (%)	Description
1	PSC	0.0%	Plain compacting concrete
2	GFC-1	0.1	0.1%glass fiber added to SCC
3	GFC-1.5	0.15	0.1%glass fiber added to SCC
4	GFC-2.0	0.2	0.1%glass fiber added to SCC
5	GFC-2.5	0.25	0.1%glass fiber added to SCC
6	GFC-3	0.3	0.1%glass fiber added to SCC

Results

Sample	Slump flow 500-750mm	T_{50}flow 2-5sec	L-box (H_2/H_1)0.8-1.0	V-funnel 6-12 sec	T5flow +3sec	Remarks
PSC	720	1.6	0.96	5	9	Low viscosity Result satisfied
GFC-1	710	1.85	0.92	7.1	10	Result satisfied
GFC-1.5	670	3.72	0.86	7.7	11	Result satisfied
GFC-2.0	655	4.56	0.81	8.3	12	Result satisfied

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GFC-2.5	640	5.04	0.78	9.2	12	Result satisfied
GFC-3	630	5.85	0.7	11.1	15	Too high viscosity Blockage

Hardened Properties
To compare the various mechanical properties of the FRSCC mixes the standard specimens were tested after 7 days and 28 day of curing. The results are summarized in following Table

S.No.	**Mixes**	**7-day compressive strength(MPa)**	**28-days compressive strength(MPa)**	**28days split tensile strength(MPa)**	**28-day flexural strength(MPa)**
1	PSC	33.185	40.6	4.12	7.3
2	GFC-1	24.82	40.92	3.12	7.52
3	GFC-1.5	33.72	46.5	4.92	9.83
4	GFC-2.0	32.7	47.4	5.02	10.15
5	GFC-2.5	31.66	45.65	3.98	9.6
6	GFC-3	23.1	39.8	3.6	8.35

ULTRASONIC PULSE VELOCITY
The UPV meter acts on principle of wave propagation hence higher the density and soundness, higher the velocity of wave in it.

S.No.	**Mixes**	**7-day UPV OF CUBE(M/sec) strength**	**28 –days UPV OF CUBE(M/sec)strength(MPa)**
1	PSC	4477.2	4408
2	GFC-1	4298.2	4392
3	GFC-1.5	4486.32	4473
4	GFC-2.0	4454	4481
5	GFC-2.5	4294	4467
6	GFC-3	4153	4372

Slab 1 M 30 grade SCC with 0% glass fibres

Slab 2. M30 grade SCC with 0.03% glass fibres

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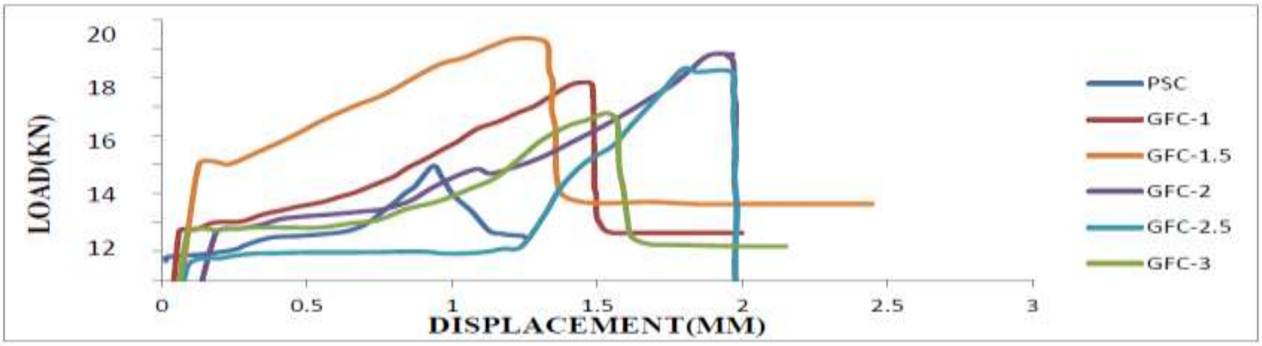
M 40 grade SCC with 0% glass fibres

M 40 GRADE SCC with 0.1% glass fibres

LOAD-CMOD BEHAVIOUR

The load vs. crack mouth opening deflection diagrams obtained clearly proved that addition of fibers to SCC increase ductility whereas control beam PSC exhibited brittle behavior. The maximum increment was observed from carbon fiber than the basalt and the lowest from the glass fiber. In each series the mix which gave maximum compressive strength rendered maximum ductility. The area below the load deflection curve represents toughness. Almost same pattern of behavior were observed from all mixes. The observations made during the tests (LOAD-CMOD) were used to draw the LOAD-CMOD curves. The ultimate load and the fracture parameters were determined.



Load-Displacement Curve for GFC

Micro structural SEM images

To study the Microstructure of the mixes incorporated with different types of fibers SEM analysis were conducted in SEM lab. The study was done to determine the bond development and different period between different fibers and cement matrix. The sample was cured for 7 and 28 days.

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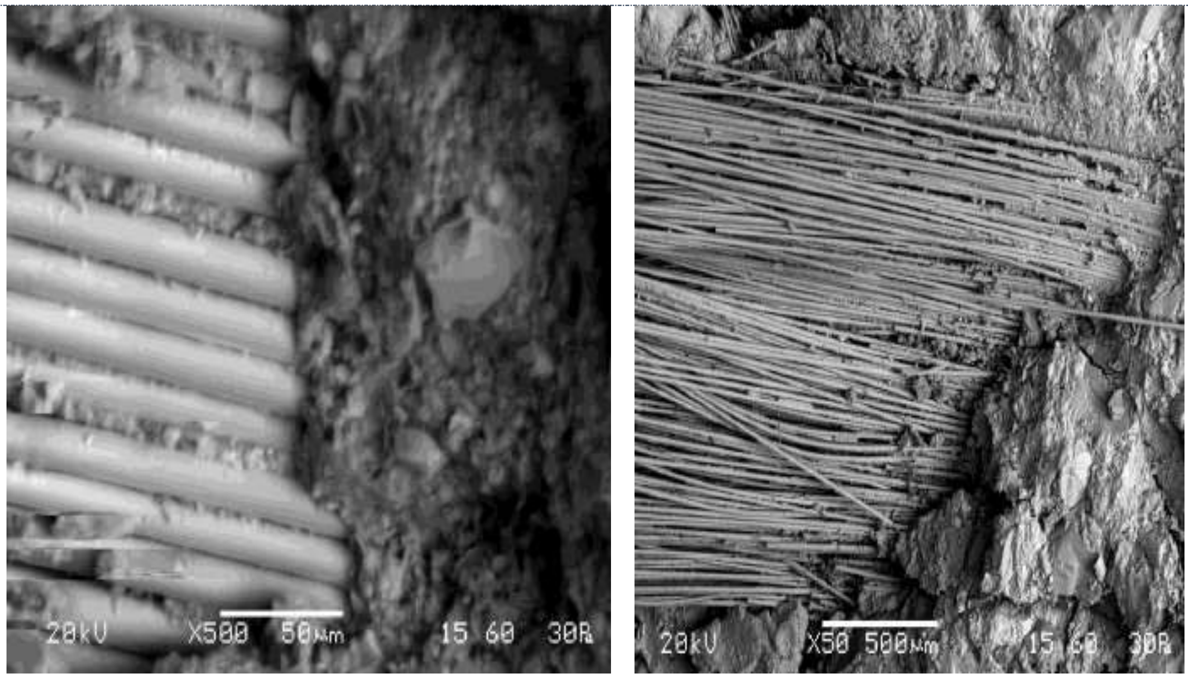

SEM photographs for (A) 7-Days & (B) 28 days concrete & glass fiber matrix

CONCLUSION

From the present study the following conclusions can be drawn

- Addition of fibers to self-compacting concrete causes loss of basic characteristics of SCC measured in terms of slump flow, etc.
- Reduction in slump flow was observed maximum with glass fiber. Addition of fibers to self-compacting concrete improve mechanical properties like compressive strength ,split tensile strength, flexural strength etc. of the mix.
- There was an optimum percentage of fiber, provided maximum improvement in mechanical properties of SCC.
- Mix having 0.15% carbon fiber, 0.2% of glass fiber were observed to increase the mechanical properties to maximum.

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