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AN ANALYSIS OF MECHANICAL AND FRACTURE BEHAVIOR OF SELF-COMPACTING CONCRETE REINFORCED WITH CHOPPED FIBRE

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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 labor 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 different types of 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 and sorptivity were studied. Microstructure study of various mixes is done through scanning electron microscope to study the hydrated structure and bond development between fibre and mix.

The fibres used in the study are 12 mm long chopped glass fibre, carbon fibre and basalt fibre. The volume fraction of fibre taken are 0.0%,0.1%,0.15%,0.2%,0.25% ,0.3%. The project comprised of two stages. First stage consisted of development of SCC mix design of M30 grade and in the second stage, different fibres like Glass, basalt and carbon Fibres are added to the SCC mixes and their fresh and hardened properties were determined and compared.

The study showed remarkable improvements in all properties of self-compacting concrete by adding fibres of different types and volume fractions. Carbon FRSCC exhibited best performance followed by basalt FRSCC and glass FRSCC in hardened state whereas poorest in fresh state owing to its high water absorption. Glass FRSCC exhibited best performance in fresh state. The present study concludes that in terms of overall performances, optimum dosage and cost Basalt Fibre is the best option in improving overall quality of self-compacting concrete.

Keywords: Self-Compacting Concrete, Glass fibre, Carbon fibre, Silica fume

I. INTRODUCTION

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 cementitious material, when it is compared to materials like steel. Concrete, this is a quasi-fragile material, having negligible tensile strength. Several studies have shown that fibre reinforced composites are more efficient than other types of composites. The main purpose of the fibre 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. De-bonding, sliding and pulling-out of the fibres are the local mechanisms that control the bridging action. In the beginning of macro cracking, bridging action of fibres 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 fibre fractions.

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

1. Glass fibres
2. Carbon fibres
3. Basalt fibres
4. Polypropylene fibres etc.

Fibres used in this investigation are of glass, basalt & carbon.

II. LITERATURE REVIEW

The relevant literature on present study was thoroughly reviewed and presented here.

Yang, F., et al. (2004) this paper investigates the technique to develop SCC as well as its components and mix proportioning methods. It highlights several benefits of using SCC and mentions to several tools used to measure its properties. Again, it reports the protective measures that should be taken for preparing and developing the mix and some model applications of SCC was proposed by the author, for example, Toronto International Airport. A high strength SCC was used for constructing compactly reinforced elements poured in beneath freezing weather for the 68 Story Trump Tower in New York cityof USA.

Senguptha, A., et al. (2006) the author founded the optimum mixture for preparation of SCC as per EFNARC 2005 code. All design mixes fulfilled the EFNARC standards and exhibited good segregation resistance, passing ability, and filling ability.For designing SCC, high amounts of powder contents were necessary. The SCC mixes with greater powder contents resulting in greater compressive strengths. A good correlation was perceived between V- funnel time and T-50 slump flow test.

Prasad, G. G., et al. (2009) author developed M60 grade SCC and compared with conventionally prepared concrete mix for hardened properties. Analytical equations for stress- strain curve proposed by different authors were verified the obtained experimental data. It was seen that the values of stock at peak stress under axial compression for both the concretes are near to 0.002 as given in IS:456-2000.

ANAND, M. V., et al (2010) The present study proposes to study the flexural behavior of SCC beams with steel fibres. An experimental program has been contrived to cast and test three plain SCC beams and six SCC beams with steel fibres. The experimental variables were the fibre content (0vf%, 0.5VF% and 1.0VF %) and the tensile steel ratio (0.99%, 1.77% and 2.51%).

Cunha, V. M., 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.

Abdulhadi, M., et al. (2012)the author prepared M30 grade concrete and added polypropylene fibre 0% to 1.2% volume fraction by weight of cement and tested the compressive and split tensile strength and obtained the relation between them.

Alberti. M. G., et al (2014) in this paper the mechanical attributes of a self-compacting concrete with low, medium and high-fibre contents of macro polyolefin fibres are considered. Their fracture behavior is compared with a manifest self-compacting concrete and also with a steel fibre-reinforced self-compacting concrete.

Jiang, C., et al (2014) in this field, the effects of the volume fraction and length of basalt fibre (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.

III. OBJECTIVE OF STUDY

The primary objectives of present Dissertation are:

- To prepare mix design of SCC of grade M30 and then investigate the effect of inclusion of chopped basalt fibre, glass fibre& carbon fibre on fresh properties and hardened properties of SCC.
- To analyze fresh concrete properties comprise of flow ability, passing ability, and viscosity related segregation resistance.
- To study the effect on hardened concrete properties namely compressive strength, splitting tensile strength, flexural strength, modulus of elasticity, Ultrasonic pulse velocity and fracture energy.
- To study of micro structures by SEM of SCC reinforced with different fibres at different ages
- To analyse the effect and improvisation of fibre orientation in self-compacting concrete.
- In the present work the mechanical properties of a self- compacting concrete with chopped Basalt, glass & Carbon fibre 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.
- To study the fracture energy behaviour, which is one parameter that is very useful in calculating the specific fracture energy, GF, by means of a uniaxial tensile test, where the complete stress-deformation curve is measured.

The present studies are designed at making standard grade (M30) fibre reinforced SCC with glass fibres, basalt fibres & carbon fibres and study their mechanical & structural behaviour.

IV. MATERIALS AND METHODS

In this study, the mechanical behaviour of fibre reinforced self-compacting concrete of M30 grade prepared with basalt fibre, glass fibre and carbon fibre 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 behaviour, fracture energy behaviour, microstructure of plain SCC, basalt fibre reinforced SCC (BFC), glass fibre reinforced SCC (GFC), carbon fibre reinforced SCC (CFC). The observational plan was held up in various steps to accomplish the following aims:

- To prepare plain SCC of M30 grade and obtain its fresh and hardened properties.
- To prepare basalt, glass & carbon fibre reinforced SCC of M30 grades and study their fresh and hardened properties.
- To analyse the load-deflection behaviour of SCC, BFRSCC, GFRSCC & CFRSCC.
- To examine the fracture energy behaviour& the micro structure of plain SCC, BFC, and GFC & CFC.

1. Cement

Portland slag cement of Khyber 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.

2. Coarse Aggregate

The coarse aggregate used were 20 mm and 10 mm down size and collected from Quarry near Budgam.

3. Fine Aggregate

Natural river sand has been collected from Dhood Ganga River, Budgam, J&K and conforming to the Zone-III as per IS-383-1970.

4. 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 .

5. Admixture

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

6. Water

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

7. Glass Fibre

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

8. Basalt Fibre

Basalt fibre of 12mm length was used in the investigations.

9. Carbon Fibre

Carbon fibre of length 12mm was used in the investigations.

Table 1. Mechanical Properties of Fibres

Fibre variety	Length (mm)	Density (g/cm³)	Elastic modulus(GPa)	Tensile strength(MPa)	Elong. at break(%)	Water absorption
BASALT	12	2.65	93-110	4100-4800	3.1-3.2	<0.5
GLASS	12	2.53	43-50	1950-2050	7-9	<0.1
CARBON	12	1.80	243	4600	1.7	

Table 2. Adopted Mix Proportions of SCC

Cement (kg/m³)	Silica fume(kg/m³)	Water(kg/m³)	FA (kg/m³)	CA (kg/m³)	SP (kg/m³)
450.33	45.03	189.13	963.36	642.24	5.553
1	0.10	0.42	2.14	1.42	0.012

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, basalt fibre reinforced SCC (BFC), glass fibre reinforced SCC(GFC), carbon fibre reinforced SCC(CFC).

Table 3. Description of Mixes

Designation	Fibre content (%)	Description
PSC	0.0%	Plain self-compacting concrete
BFC-1	0.1%	0.1% Basalt fibre reinforced SCC
BFC-1.5	0.15%	0.15%Basalt fibre reinforced SCC
BFC-2	0.2%	0.2%Basalt fibre reinforced SCC
BFC-2.5	0.25%	0.25%Basalt fibre reinforced SCC
BFC-3	0.3%	0.3%Basalt fibre reinforced SCC
GFC-1	0.1%	0.1%Glass fibre reinforced SCC
GFC-1.5	0.15%	0.15%Glass fibre reinforced SCC
GFC-2	0.2%	0.2%Glass fibre reinforced SCC
GFC-2.5	0.25%	0.25%Glass fibre reinforced SCC
GFC-3	0.3%	0.3%Glass fibre reinforced SCC
CFC-1	0.1%	0.1%Carbon fibre reinforced SCC
CFC-1.5	0.15%	0.15%Carbon fibre reinforced SCC
CFC-2	0.2%	0.2%Carbon fibre reinforced SCC

Methods to determine the fresh properties of SCC:

- Slump Flow Test and T50 Test
- V-FunnelTest
- L-Box Test

Testing Of Hardened SCC:

- Compression Test
- Split Tension Test
- Flexural Strength
- Ultrasonic Pulse Velocity Test

Other Studies:

- Studies on Fracture Behavior of SCC and Frscc Mixes
- Studies on Load-Deflection Behavior of SCC and Fibre Reinforced SCC Mixes
- Studies on Sem Analysis of Fibre Reinforced SCC Mixes
- Studies on Sorptivity Test of Fibre Reinforced SCC Mixes

V. RESULTS AND DISCUSSIONS

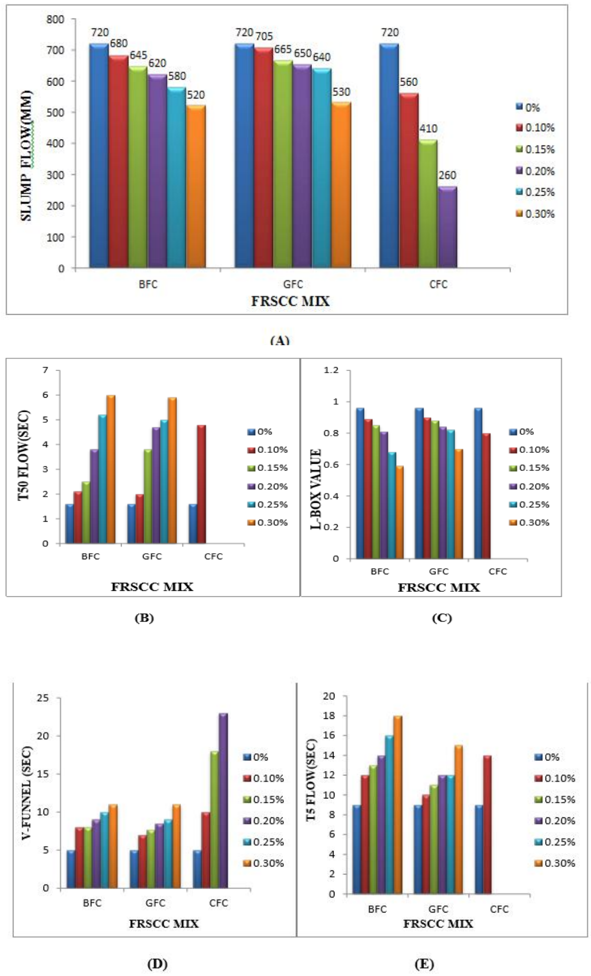

Fig.1 (A),(B),(C),(D),(E) Variation of Fresh properties with FRSCC Mix#

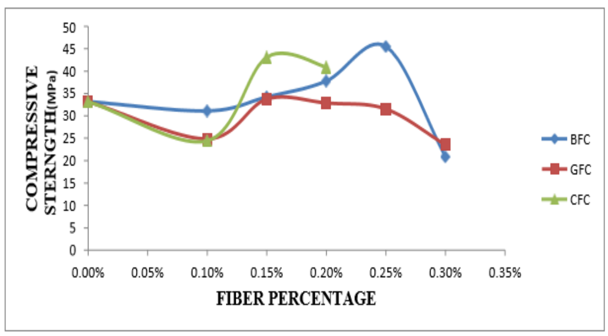

Fig. 2 Comparison of Different Percentages of Fibre Mixes with 7 days Compressive Strength

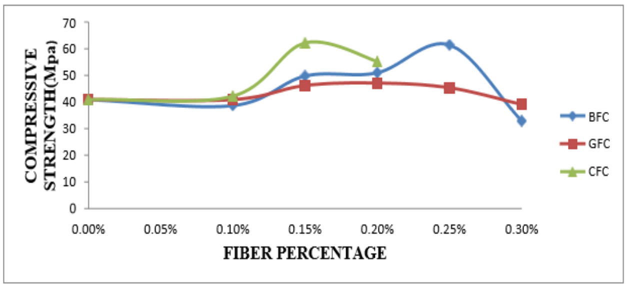

Fig. 3 Comparison of Different Percentages of Fibre Mixes with 28 days Split Tensile Strength

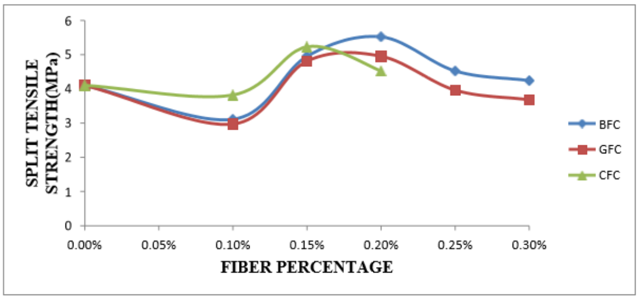

Fig. 4. Comparison of Different Percentages of Fibre Mixes with 28 days Split Tensile Strength

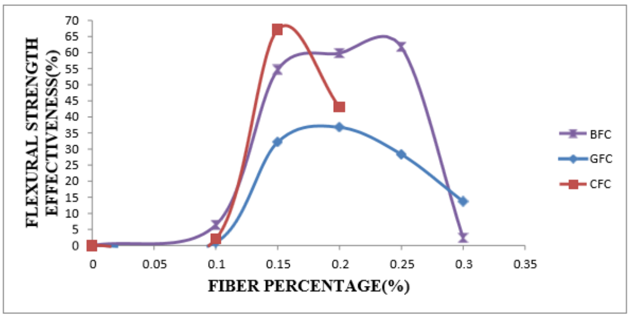

Fig. 5 Flexural Strength-Effectiveness of FRSCC at 28-Days

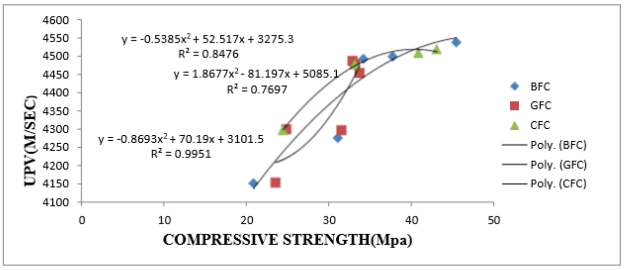

Fig. 6 Correlation Curves between Avg. UPV values & 7-days Compressive Strength

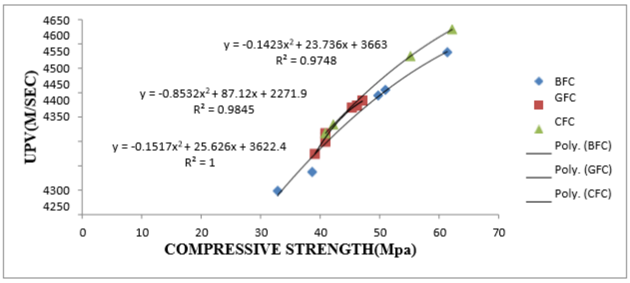

Fig.7 Co-Relation between Avg. UPV & 28-days Compressive Strength

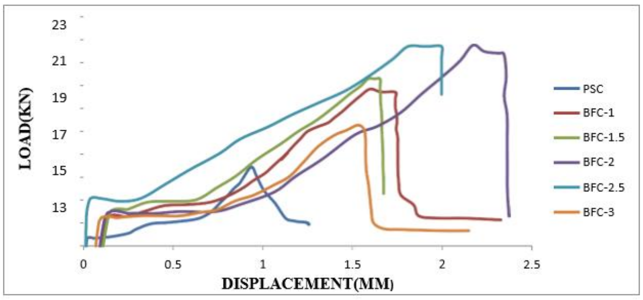

Fig. 8 Load-Displacement Curve For BFC

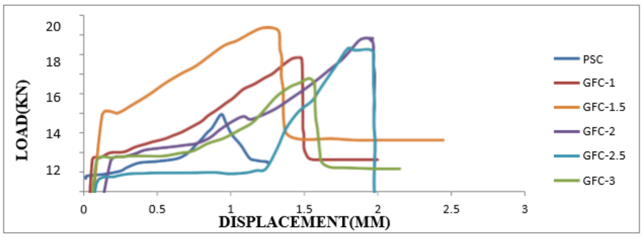

Fig. 9 Load-Displacement Curve For GFC

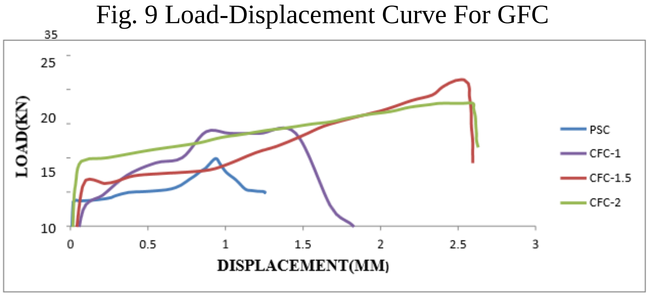

Fig. 10 Load-Displacement Curve For CFC

VI. CONCLUSIONS

In the present study the following conclusions have been made;

- Addition of fibres 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 carbon fibre, then basalt and glass fibre respectively. This is because carbon fibres absorbed more water than others and glass absorbed less.
- Carbon fibre addition more than 2% made mix harsh which did not satisfy the aspects like slump value, T50 test etc. required for self-compacting concrete.
- Addition of fibres 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 each type of fibre, provided maximum improvement in mechanical properties of SCC.
- Mix having 0.15% carbon fibre, 0.2% of glass fibre and 0.25% of basalt fibre were observed to increase the mechanical properties to maximum.
- 0.15% addition of carbon fibre 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 27.56%, flexural strength by 67.16%.

- 0.25% addition of basalt fibre 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 34.56%, flexural strength by 61.736%.
- 2% addition of glass fibre to SCC was observed to increase the 7-days compressive strength by 1.76%, 28-days compressive strength by 15.21%, split tensile strength by 20.73%, flexural strength by 36.77%.

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