# A STUDY ON MECHANICAL PROPERTIES AND FRACTURE BEHAVIOR OF FIBEROUS SELF-COMPACTING CONCRETE

**B. RAVITEJA[1]** **M.VENKATA NARASAIAH[2]**

PG Scholar (Structural Engineering) Assistant Professor (Civil Engineering Department)

*[1,2]CHEBROLU ENGINEERING COLLEGE CHEBROLU (MD); GUNTUR (DT); AP*

---------------------------------------------------------------------***---------------------------------------------------------------------

**ABSTRACT** :- Transportation is major factor in the world. In that bituminous pavements playing a prominent 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 behaviour 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 fiber and mix.

The fibers used in the study are 12 mm long chopped glass fiber, carbon fiber and basalt fiber. The volume fraction of fiber 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 fibers like Glass, basalt and carbon Fibers 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 fibers 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 Fiber is the best option in improving overall quality of self-compacting concrete.

## I. INTRODUCTION

It is a concrete which is considered to placed and compacted every part of the corner of the formwork, even in the presence of dense reinforcement, purely by means of own weight and less or no vibrational effort. However, various investigations are moving on in various characteristics of the mechanical behaviour and structural applications of SCC.SCC has established to be effective material, so there is a need to guide further investigation on the normalization of self-consolidating characteristics and its behaviour to apply on different structural construction, and its usage in all perilous and inaccessible project zones for superior quality control. Several studies have shown that fibre reinforced composites are more efficient than other types of composites. The key determination of the fibre is to restrict cracking and to increase the fracture toughness of the brittle matrix through bridging action in both micro and macro cracking of the matrix. At initial stage and the hardened state, Inclusion of fibres improves the properties of the concrete especially of the high performance concrete like SCC. Hence researchers have focused on study of the strength and durability aspects of fibre reinforced SCC. This mechanism growths the demand of energy for the crack to propagate. The linear elastic behaviour of the matrix is not affected significantly for low volumetric fibre fractions. The objective of present research is to mix design of SCC of grade M30 and to investigate the effect of inclusion of chopped steel fibre on fresh properties and hardened properties of SCC. The effects of the volume fraction and length of steel fibre (SF) on the mechanical properties of FRC were analysed. The outcomes indicate that adding SF significantly improves the tensile strength, flexural strength and toughness index, whereas the compressive strength shows no obvious gain. Furthermore, the length of SF presents an influence on the mechanical properties. 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, and fracture test.

## II. EXPERIMENTAL PROGRAMME

**2.1 MATERIALS:-** Portland slag cement [1] of Ultra-Tech brand available in the local market was used in the present studies. The coarse aggregate used were 20 mm and 10 mm down size. Natural river sand has been collected from River, and conforming to the Zone-III as per IS-383-1970 [2].Fly ash is used. The SikaViscocrete Premier from Sika is super plasticizer and viscosity modifying admixture. Steel fibre of length 12mm of 0%, 0.05%, 0.1%, 0.15%, and 0.2% volume fraction by weight of the total weight of concrete was used in the investigations.

**MECHANICAL PROPERTIES OF FIBERS**

| Property | BASALT | GLASS | CARBON |
|---|---|---|---|
| Length(mm) | 12 | 12 | 12 |
| Density(g/cm$^3$) | 2.65 | 2.53 | 1.80 |
| Elastic Modulous(GPa) | 93-110 | 43-50 | 243 |
| Tensile Strength(Mpa) | 4100-4800 | 1950-2050 | 4600 |
| Elong.at break(%) | 3.1-3.2 | 7-9 | 1.7 |
| Water Absorption | <0.5 | <0.1 | -- |

**2.2 EXPERIMENTAL PROCEDURE:-** The mixing of materials properly mixed in a power operated concrete mixer. Adding coarse aggregate, fine aggregates, cement and mixing it with fly ash properly mixed in the concrete mixer in a dry state for a few seconds. Then the water added and mixing it for three minutes. During this time the air entraining agent and the water reducer are also added. Dormant period was 5mins. To obtain the steel fiber reinforced SCC, the required fiber percentage was added to the already prepared design mix, satisfying the fresh SCC requirements. Calculation for M30 grade of SCC was done following EFNARC code 2005 in the mix design 15% of fly ash use as a replacement for cement to achieve the target strength. Viscocrete admixture was used to reduce the water content and improve workability as per the requirement for SCC.

**Adopted Mix Proportions of SCC**

| | | |
|---|---|---|
| CEMENT(kg/m$^3$) | 450.33 | 1 |
| Silica Fume(kg/m$^3$) | 45.03 | 0.10 |
| Water(kg/m$^3$) | 189.13 | 0.42 |
| FA(kg/m$^3$) | 963.36 | 2.14 |
| CA(kg/m$^3$) | 642.24 | 1.42 |
| SP(kg/m$^3$) | 5.553 | 0.012 |

**2.3 CASTING OF SPECIMENS:-** Forty two number cubes (150×150×150) mm, forty two numbers cylinders (150×300) mm & forty two numbers prisms (100×100×500) mm were cast and investigations were conducted to study the mechanical behaviour, fracture behaviour of steel fibre reinforced SCC (SFC)

**2.4 TESTS ON FRESH CONCRETE:-** To determine the fresh properties of SCC, different methods were developed. Slump flow and V-Funnel tests have been proposed for testing the deformability and viscosity respectively. L-Box test have been proposed for determining the segregation resistance.

**2.5 TESTS ON HARDENED CONCRETE:-** 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.

## III. RESULTS & DISCUSSIONS

**Results of the Fresh Properties of Mixes**

| sample | Slump flow 500-750mm | V-Funnel 6-12sec |
|---|---|---|
| PSC | 720 | 5 |
| BFC-1 | 680 | 8 |
| BFC-1.5 | 645 | 8 |
| BFC-2 | 620 | 9 |
| BFC-2.5 | 580 | 10 |
| BFC-3 | 520 | 11 |
| GFC-1 | 705 | 7 |
| GFC-1.5 | 665 | 7.7 |
| GFC-2 | 650 | 8.5 |
| GFC-2.5 | 640 | 9 |
| GFC-3 | 530 | 11 |
| CFC-1 | 560 | 10 |
| CFC-1.5 | 410 | 18 |
| CFC-2 | 260 | 23 |

**Hardened Concrete Properties of SCC and FRSCC**

**Flexural Strength**

| Mixes | 28-days split tensile strength (MPa) | 28-days flexural strength (MPa) |
|---|---|---|
| PSC | 4.1 | 7.37 |
| BFC-1 | 3.11 | 7.84 |
| BFC-1.5 | 4.95 | 11.4 |
| BFC-2 | 5.517 | 11.78 |
| BFC-2.5 | 4.52 | 11.92 |
| BFC-3 | 4.24 | 7.54 |
| GFC-1 | 2.97 | 7.44 |

| | | |
|---|---|---|
| GFC-1.5 | 4.81 | 9.74 |
| GFC-2 | 4.95 | 10.08 |
| GFC-2.5 | 3.96 | 9.46 |
| GFC-3 | 3.678 | 8.32 |
| CFC-1 | 3.82 | 7.52 |
| CFC-1.5 | 5.23 | 12.32 |
| CFC-2 | 4.52 | 10.54 |

**Compressive strength**

| Mixes | 7-Day compressive strength (MPa) | 28-days compressive strength (MPa) |
|---|---|---|
| PSC | 33.185 | 40.89 |
| BFC-1 | 31.11 | 38.67 |
| BFC-1.5 | 34.22 | 49.77 |
| BFC-2 | 37.77 | 50.99 |
| BFC-2.5 | 45.48 | 61.4 |
| BFC-3 | 20.89 | 32.89 |
| GFC-1 | 24.88 | 40.89 |
| GFC-1.5 | 33.77 | 46.19 |
| GFC-2 | 32.89 | 47.11 |
| GFC-2.5 | 31.55 | 45.33 |
| GFC-3 | 23.55 | 39.11 |
| CFC-1 | 24.44 | 42.22 |
| CFC-1.5 | 43.11 | 62.22 |
| CFC-2 | 40.89 | 55.2 |

**Ultrasonic Pulse Velocity Results**:-

| SPECIMEN | 7-DAYS AVG. UPV OF CUBE (M/SEC) | 28-DAYS AVG. UPV OF CUBE (M/SEC) |
|---|---|---|
| PSC | 4477.6 | 4416.34 |
| BFC-1 | 4275.43 | 4337 |
| BFC-1.5 | 4492 | 4493.67 |
| BFC-2 | 4498.67 | 4505.33 |
| BFC-2.5 | 4537.67 | 4582.33 |
| BFC-3 | 4151.34 | 4298.33 |
| GFC-1 | 4299.34 | 4399 |
| GFC-1.5 | 4486.67 | 4473 |
| GFC-2 | 4454 | 4483.67 |
| GFC-2.5 | 4296.67 | 4469.33 |
| GFC-3 | 4153 | 4374 |
| CFC-1 | 4296.67 | 4434.34 |
| CFC-1.5 | 4518.6 | 4629.66 |
| CFC-2 | 4508.34 | 4574.67 |

## IV. CONCLUSIONS

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 carbon fiber, then basalt and glass fiber respectively.

This is because carbon fibers absorbed more water than others and glass absorbed less.

- Carbon 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.
- 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 each type of fiber, provided maximum improvement in mechanical properties of SCC.
- Mix having 0.15% carbon fiber, 0.2% of glass fiber and 0.25% of basalt fiber were observed to increase the mechanical properties to maximum.
- 0.15% addition of carbon 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 27.56%, flexural strength by 67.16%.
- 0.25% addition of basalt 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 34.56%, flexural strength by 61.736%.

**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)pp 1799-1807.
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. Hajime Okamura and Masahiro Ouchi ; Invited Paper on "Self Compacting Concrete"-Journal of Advanced Concrete Technology Vol.1, No.1, pp5-15, April 2003 Japan Concrete Institute.