International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 09 Issue 12 ǁ 2021 ǁ PP. 12-17

A Study on Mechanical Properties and Fracture Behavior of Chopped Fiber Reinforced Self-Compacting Concrete

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Abstract:
The growth ofSelf Compacting Concrete is revolutionary landmark in the history of construction industry resulting inpredominant usage of SCC worldwide nowadays. It has many advantagesover normal concrete in terms of enhancement in productivity, reductionin labor and overallcost, excellent finished product with excellent mechanical response and durability. Incorporationof fibers further enhances its properties specially related to post crack behavior of SCC. Hencethe aim of the present work is to make a comparative study of mechanical properties of self-consolidating concrete, reinforced with different types of fibers. The variables involve in thestudyaretypeanddifferentpercentageoffibers.ThebasicpropertiesoffreshSCCandmechanical properties, toughness, fracture energy and sorptivity were studied. Microstructurestudy of various mixes is done through scanning electron microscope to study the hydratedstructureand bond development between fiber and mix.The fibers used in the study are 12 mm long chopped glass fiber, carbon fiber and basalt fiber.Thevolumefractionoffibertakenare0.0%,0.1%,0.15%,0.2%,0.25%,0.3%.Theprojectcomprised of two stages. First stage consisted of development of SCC mix design of M30 gradeand in the second stage, different fibers like Glass, basalt and carbon Fibers are added to the SCCmixesandtheirfreshandhardened properties weredeterminedandcompared.The study showed remarkable improvements in all properties of self-compacting concrete byaddingfibersofdifferenttypesandvolumefractions.CarbonFRSCCexhibitedbestperformance followed by basalt FRSCC and glass FRSCC in hardened state whereas poorest infresh state owing to its high water absorption. Glass FRSCC exhibited best performance in freshstate. The present study concludes that in terms of overall performances, optimum dosage andcostBasaltFiberis thebestoption in improvingoverall qualityof self-compactingconcrete.

Date of Submission: 08-12-2021 Date of acceptance: 23-12-2021

I. INTRODUCTION:

Self-compacting concrete was originally developed in Japan and Europe. It is a concrete that isable to flow and fill every part of the corner of the formwork, even in the presence of densereinforcement, purely by means of own weight and without the need of for any vibration or othertypeofcompaction.

The growth of Self Compacting Concrete by Prof. H.Okamura in 1986 has caused a significantimpact on the construction industry by overcoming some of the difficulties related to freshlyprepared concrete. The SCC in fresh form reports numerous difficulties related to the skill ofworkers, density of reinforcement, type and configuration of a structural section, pump-ability,segregation resistance and, mostly compaction. The Self Consolidating Concrete, which is rich infines content, is shown to be more lasting. First, it started in Japan; numbers of research werelisted on the global development of SCC and its micro-social systemand strength aspects.Though, the Bureau of Indian Standards (BIS) has not taken out a standard mix method whilenumber of construction systems and researchers carried out a widespread research to find propermix design trials and self-compact ability testing approaches. The work of Self CompactingConcrete is like to that of conventional concrete, comprising, binder, fine

Aggregates and coarseaggregates,water,finesandadmixtures.To adjust therheologicalpropertiesofSCCfromconventional concrete which is a remarkable difference, SCC should have more fines content,superplasticizers with viscositymodifyingagentsto some extent.

As compared to conventional concrete the benefits of SCC comprising more strength like nonSCC,maybehigherduetobettercompaction,similartensile strength likenonSCC,modulusof elasticity may be slightly lower because of higher paste, slightly higher creep due to paste,shrinkage as normal concrete, better bond strength, fire resistance similar as non SCC, durabilitybetterforbetter surfaceconcrete.

Addition of more fines content and high water reducing admixtures make SCC more sensitivewith reduced toughness and it designed and designated by concrete society that is why the use ofSCC in a considerable way in making of pre-cast products, bridges, wall panels etc. also in somecountries.However, various investigations are carried out to explore various characteristics and structuralapplications of SCC. SCC has established to be effective material, so there is a need to guide onthe normalization of self-consolidating characteristics and its behavior to apply on differentstructural construction, and its usage in all perilous and inaccessible project zones for superiorqualitycontrol.

II. LITERATUREREVIEW:

Fiber reinforced SCC are currently being studied and applied around the world for the increasingof tensile and flexural strength of structural concrete members. The literature review has beensplit up into three parts, namely super plasticizers, preparation of SCC, Fiber-Reinforced SCC asgivenunder.

SUPERPLASTICIZERS

M Ouchi, et al. (1997) the authors have specified the influence of Super Plasticizers on theflow-ability and viscosity of Self Consolidating Concrete. From the experimental investigationauthor suggested an overview the effect of super plasticizer on the fresh properties of concrete.Author found his studies were very convenient for estimating the amount of the Super Plasticizertosatisfyfresh propertiesof concrete.

GaoPeiwei., et al. (2000) the authors hasstudiedspecial type of concrete, in which sameingredients are used like conventional concrete. Keeping in mind to produce high performanceconcrete,mineraland chemical admixtureswithViscosityModifyingAgents(VMA),arenecessary.Theobjectiveistodecreasetheamountofcementin HPC.Preserving valuable naturalresources is the primary key, then decrease the cost and energy and the final goal is long-termstrength &durability.

DEVELOPMENT OF SELF COMPACTING CONCRETE

Okamura et al. (1995) author established a special type of concrete that flows and getscompacted at every place of the formwork by its own weight. This research work was startedcombined by prof. Kokubu of Kobe University, Japan andProf. Hajime Okamura. Previously itwas used as anti washout concrete. They initiate that for attainment of the self-compact ability,usage of Super Plasticizer was necessary.The water/cement ratio should be in between 0.4 to 0.6.The self-compactability of the concrete is mainly affected by the material characteristics and mixproportions. Author restricted the coarse aggregate content to 60% of the solid volume and thefine aggregate content to 40% to attain self-compactability.

KhayatK.H,etal.(1999)authored liberatethebehaviorofViscosityEnhancing Admixtures used in cementious materials. He has determined that, a fluid without washout-resistant should be formed by properly modifying the mixtures of VEA and High Range WaterReducing agents, that will improve properties of underwater cast grouts, mortars, and concretes,anddecreases the turbidity,andrisesthe pHvalues of surroundingwaters.

FIBER REINFORCED SELF-COMPACTING CONCRETE

M. VIJAYANAND, et al (2010) The present study proposes to study the flexural behaviorof SCC beams with steel fibers. An experimental program has been contrived to cast and testthree plain SCC beams and six SCC beams with steel fibers. The experimental variables were thefiber content (0vf%,0.5VF% and1.0VF %) and the tensile steelratio (0.99%,1.77% and2.51%).

V.M.C.F. Cunha, et al. (2011) the author establishes numerical model for the ductilebehavior of SFRSCC. They have presumed SFRSCC as two phase material. By 3-D smearedcrackmodel,thenonlinearmaterialbehaviorofself-compactingconcreteisapplied.Themathematicalmodel presentedgoodrelationshipwith experimental values.

Mustapha Abdulhadi, et al. (2012)the author prepared M30 grade concrete and addedpolypropylene fiber 0% to 1.2% volume fraction by weight of cement and tested the compressiveandsplit tensilestrengthand obtained therelation between them.

M.G. Alberti. Et al (2014) in this paper the mechanical attributes of a self-compactingconcrete 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 asteelfiber-reinforced self-compactingconcrete.

Chihuahua Jiang, et al (2014) in this field, the effects of the volume fraction and length ofbasalt fiber (BF) on the mechanical properties of FRC were Analyzed.The outcomes indicate thatadding BF significantly improves the tensile strength, flexural strength and toughness index,whereas the compressive strength shows no obvious gain. Furthermore, the length of BF presentsaninfluenceon themechanical properties.

III. MATERIALSANDPROPERTIES:

Cement

Portland slag cement of Konark 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 Quarry near Baddi.

Fine Aggregate

Natural river sand has been collected from Stone crusher of Mr. Ram Kumar Chaudhary, Bhud, Baddi and conforming to the Zone-III as per IS-383-1970.

SilicaFume

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 Sika ViscoCrete Premier from Sika is super plasticizer and viscosity modifying admixture,usedin thepresent study.

Water

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

GlassFiber

Alkaliresistantglassfiber havingamodulus ofelasticityof72GPA and12mmlength wasused.

BasaltFiber

Basaltfiberof12mmlengthwasusedintheinvestigations.

CarbonFiber

Carbonfiberoflength12mm wasusedintheinvestigation.

Mechanical Properties of Fibers

Fiber variety	Length (mm)	Density (g/cm^3)	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	

Design mix:

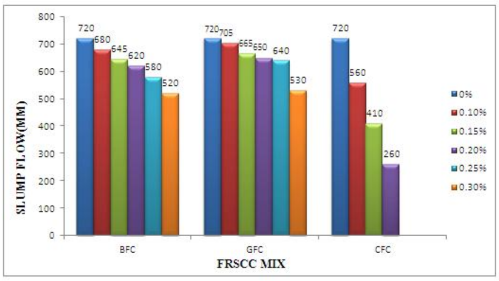
Cement (kg/m^3)	Silica fume(kg/m^3)	Water(kg/m^3)	FA(kg/m^3)	CA(kg/m^3)	SP(kg/m^3)
450.33	45.03	189.13	963.36	642.24	5.553
1	0.10	0.42	2.14	1.42	0.012

TESTRESULTS AND DISCUSSION:

Propertiesin Freshstate:

Slump Flow

The slump flow decreases with increase in fiber percentage. The decrease in flowvalue isobserved maximum 63.88% for carbon fiber, 26.38% for glass fiber and 27.77 % for basaltfiberw.r.t control mix.

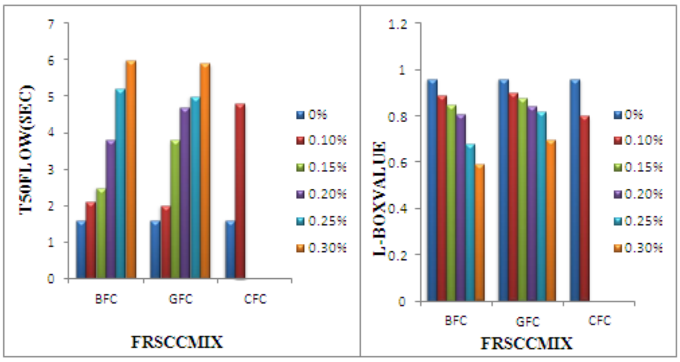


T50Flow

The T50 flow, which was measured in terms of time (seconds) increases as the slump flow valuedecreases.Thedecreaseinslumpvalueisduetotheincreaseinthepercentageoffiberwhich was explained in previous section. The maximum time taken to flow was observed at 0.1% forcarbonfiber, 0.3%for glass fiber and 0.3%forbasalt fiber.

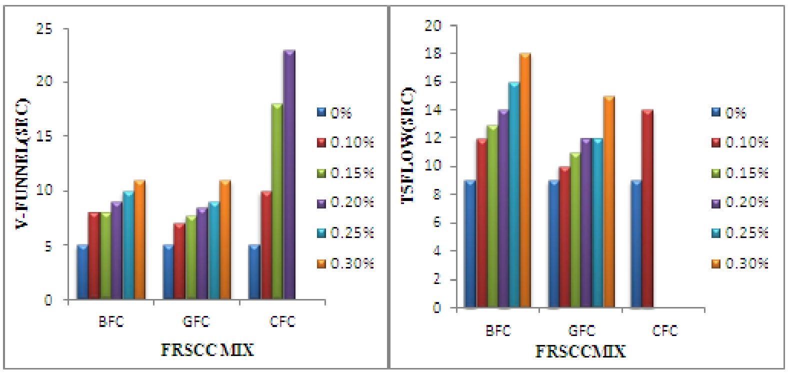
L-Box

The L-Box value increases as the slump flow value increases. The increase in slump value is duetotheincreaseinthepercentageoffiberaswellastheL-Boxvaluealsoincreases.Themaximum value obtained in the case of control mix but as per SCC specification 0.2% basaltfiber.0.25%glass fiber&0.1%carbonfiber fulfill the requirements.



V-Funnel&T5flow

The V-Funnel test & T50 flow, which was measured in terms of time (seconds) & both the valuemeasuredare dependentwith each other. V-Funnel valueand T5flow increases asthe slumpflow value decreases. The decrease in slump value is due to the increase in the percentage offiber. It was observed that at 0.1% of carbon fiber, 0.2% of basalt fiber and 0.25% of glass fibertheSCC specification weresatisfied

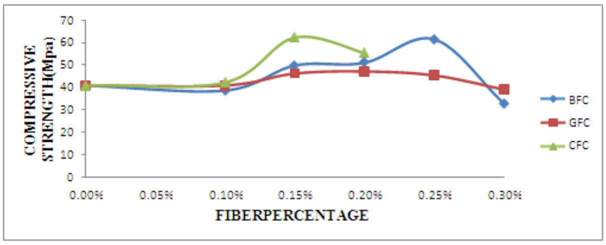


Hardened Properties

To compare the various mechanical properties of the FRSCC mixes the standard specimens were tested after 7 days and 28 days of curing.

Compressive Strength

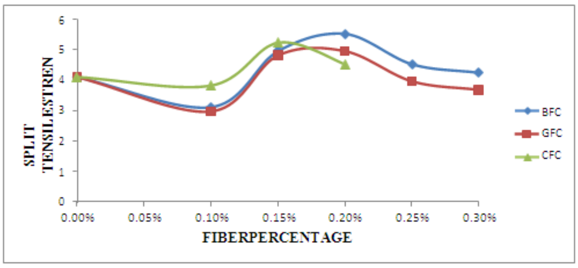
The fig.below shows the optimum fiber content in mixes with different fibers. The maximumstrength of 61.4 MPa was observed with 0.25% basalt fiber content,60.35 MPa was observedwith 0.15% carbon fiber content and 47.11 MPa was observed with 0.2% glass fiber content.Thehighest28-dayscompressivestrengthwasobservedformixwith0.25%basaltfiberandlowestformixwith 0.3% basalt fiber.



Comparison of Different Percentages of Fiber Mixes with 28 days CompressiveStrength

Tensile Strength

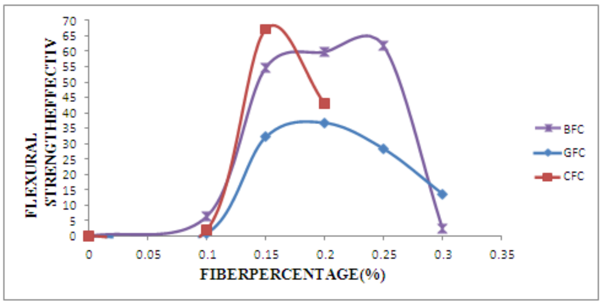
The Fig. below shows the optimum fiber content in mixes with different fibers. The maximum strength of 5.517MPa was observed with 0.2% basalt fiber content,5.23MPa was observed with0.15% carbon fiber content and 4.95MPa was observed with 0.2% glass fiber content. The highest 28-days split tensile strength was observed for mix with 0.2%basalt fiber and lowest for mix with 0.1%glass fiber.



Comparison of Different Percentages of Fiber Mixes with 28 days Split Tensile Strength

Flexural Strength

The Fig. 4.3.8 shows the optimum fiber content in mixes with different fibers. The maximumstrength of 12.32MPa was observed with 0.15% carbon fiber content,11.92MPa was observedwith 0.25% basalt fiber content and 10.08MPa was observed with 0.2% glass fiber content. Thehighest 28-days flexural strength was observed for mix with 0.15%carbon fiber and lowest formixwith 0.1%glass fiber.



FlexuralStrength-EffectivenessofFRSCCat28-Days

ULTRASONIC PULSE VELOCITY

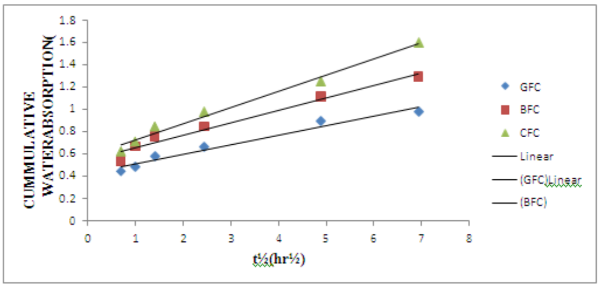
The UPV meter acts on principle of wave propagation hence higher the density and soundness,higher thevelocityof wavein it.

The addition of silica fume, having micro grains acts like filler and improve density, whereassuper-plasticizer facilitate the uniform distribution of all particles including fiber and impartcohesiveness to the mixes. These factors improve density and homogeneity of mixes in shortoverallsoundnessofconcreteimproves.Theresultsindicatesthat1%fiberadditionwereineffective in improving the UPV value in fact they were observed to be less than SCC withoutfiber.Ineachcasetherewereanoptimumpercentageoffibersexhibitingmaximum UPVvalues.

SORPTIVITY

Sorptivity is a measure of the capillary force exerted by the pore structure causing fluids to be drawn into the body of the material. t is calculated as the rate of capillary rise in a concrete prism placed in 2to5mm deep water.

Thecapillarywaterabsorptionintermstime(squarerootoftimeinhours)isplottedin fig. given below. The water absorption for CFC samples is the higher than BFC & GFC samples, which isdue to the additional water absorbed by the fibers. The higher sorptivity value was obtained forspecimenscontainingCFC fibers.



IV. Conclusion:

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 carbon fiber, then basalt and glass fiber respectively. This is because carbon fibers absorbed more water than others and glass absorbed less.
3. 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.
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. Glass FRSCC exhibited improvement in all mechanical properties especially in early ages, with higher volume fraction. It showed better performances in fresh state. Apart from being cheapest its performance in fresh state but displayed minimum strength, highest sorptivities.

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