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Comparative Study on Properties of High Strength Hybrid FRC with Conventional Concrete

Sharath B[1,] Pavankumar VS[2], Rangaswamy G[3], Sameera siyam[4], Shilpa NG[5]

[1]Assistant Professor, Dept of Civil Engineering , Dr Ambedkar Institute of Technology Bangalore Karnataka
[2,3,4,5]UG Student, , Dept of civil engineering , Dr Ambedkar institute of technology Bangalore Karnataka India

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ABSTRACT:Concrete is the most common materials used in the construction industries. In the past fewyears, many and modification has been done to produce concrete which has the desiredcharacteristics.Thereisalwaysasearchforconcretewithhigherstrengthanddurability.Plainconcretehas goodcompressivestrengthbuthaslowtensilestrength,lowductilityandlowfireresistance. The aim is to study characteristics and comparison of the mechanical properties ofsteel and glass fiber reinforce concrete with conventional concrete. In order to achieve andverifythat 0%,1%,2%ofsteel fiberto thevolume ofconcreteand 0%, 0.06%,0.09%ofglassfibertothevolumeofconcretewith theconcretemixM40grade.3,7,14&28dayscompressivestrength,spilttensilestrength,flexuralstrength,testshavetobeperformedinthehardened state. In this project the behavior of cube, cylinder & beam structures strengthenbyusingFRCistobeexperimentallytested.Thefiberusedaresteelandglassfibersinvariousvolumefractionthemainreasonforaddingsteelfibertoconcretematrixistoimprovethepostcracking response of the concrete i.e. to improve its energy absorption capacity and apparentductility and to provide a crack resistance and crack control and addition of glass fiber forbridgingthemicro-cracksaresuggestedasthereasonfortheenhancementinflexuralstrength.

KEYWORD:Concrete,Ductility, FRC,Strength, micro-crack,steelfiber,glassfiber.

I. INTRODUCTION

Fiber reinforced concrete (FRC) is a composite material consisting of cement, sand, coarseaggregate, water and fibers. In this composite material, short discrete fibres are randomlydistributedthroughouttheconcretemass.The behavioralefficiencyofthiscompositematerialisfarsuperiortothatofplainconcreteandmanyotherconstruction materialsofequalcost.Duetothisbenefit,theuseofFRC hassteadilyincreasedduringthelasttwodecadesandits current field of application includes: airport and highway pavements, earthquake-resistantand explosive-resistant structures, mine and tunnel linings, bridge deck overlays, hydraulicstructures,rock-slope stabilization,etc.

Extensive research work on FRC has established that addition of various types of fibres suchas metallic and non-metallic fibers like steel, glass, synthetic, and carbon, in plain concreteimproves strength, toughness, ductility, post-cracking resistance, etc. These hooked end steelfibres and Alkali resistance glass fiber can effectively be used for making high-strength FRCafter exploring their suitability. In this investigation, therefore, an attempt has been made tostudy the feasibility of using two kinds of fibres for making FRC. Cementitious materials aregenerally quite brittle, with relatively low strength and strain capacity under tension. Hence ahand-laid steel bar reinforcement is usually necessary to increase tensile strength. For lowreinforcementlevels,thepartialorevencompletereplacementofthisconventionalreinforcementbyfibers is an advantageous alternative. Theorientationsanddistributionsoffibersaffectthepropertiesof FRCsuchas toughness, strength, ductilityand crackwidth.

It is important to have a combination of low and high modulus fibers to arrest the micro andmacro cracks, respectively. Another beneficial combination of fibers is that of long and shortfibers. Once again, different lengths of fibers would control different scales of cracking. Theobjective of this study was to evaluate the mechanical properties of various fiber reinforcedconcretesystems,Forconventionalconcrete andhybridfiberreinforcedconcretewithcombination of steel fiber and alkali resistance glass fiber. The total dosage of fibres wasmaintainedat 0%,1%,&2%primarilyfromthepointofviewofprovidi ng goodworkability.A comparative evaluation of various hybrid fibre concretes was made based on hardenedconcretepropertiescompressive,splitandflexuralstrength.Concreteisabrittlematerialwitha low straincapacity.Fibers provide mechanisms that abate their unstable propagation,provideeffectivebridging,andimpartsourcesof strengthgain,toughnessandductility.

Thefibrescanbedividedintotwogroups:

1. Fibres that have a moduli value lesser than the cement matrix. Examples are: Glass,Nylon,cellulose andpolypropylene
2. Fibresthathave agreatermoduli valuethan cement. Examplesarethe steel,asbestosfibersetc.

Type-1fibersaresaidtoincreasethestrainperformanceoftheconcrete

Type-2 fiber has greater modulus than cement and provides greater strength performance fortheconcrete.

The addition of more fibers into the concrete mixtures makes it more homogeneous andisotropic in nature. This brings a conversion of concrete nature from brittle to the ductilecondition.Thisenhancestheductilitybehaviorof theconcrete undercritical loads.

1.1 HYBRIDFIBERREINFORCEDCONCRETE

Ahybridfiberreinforcedconcreteis acomposite oftwoormorefibersinconcrete. The concept of using fibers as a reinforcement in the concrete mixture is not a new study.Theuse of fibers has been carried out from ancient times.

There are different types of fiber reinforced concrete that are categorized based on the fiberthat is employed. If steel fiber is used we get steel fiber reinforced concrete. Similarly, nylonreinforced concrete, glass fiber reinforced concrete, carbon fiber reinforced concrete etc. aresomeofthe types.

Acomposite can bestated as a hybrid when two or moretypeoffibers is used in acombinedmatrix to produce a composite that will reflect the benefit of each of the individual fiberused. This will finally provide a synergetic response to the whole structure. Such acompositeof concreteistermedas theHybrid Fiber ReinforcedConcrete(HFC).

1.2 TENSILEBEHAVIOROFHYBRIDFIBERCONCRETE

The main aim regarding the tensile strength of hybrid fiber reinforced concrete is to attainmaximum tensile strength at minimum use of fibers. Hence the optimum amount of fiberswill be used in the concrete is based on the strength obtained from the concrete. For this, aseries of tensile strength tests is carried out. Initially, to determine the combination of fibersto be employed, flexural tests are carried out**.** This is followed by Uniaxial tensile tests,which is performed only on the selected HFC. This is to finally evaluate the tensileproperties.Thetest results providethe main basisforHPC utilization.

The basic factors of fibers that affect the tensile properties of Hybrid Fiber concreteare:

1. TypeofFiber
2. QuantityofFiber
3. OrientationofFiber
4. NumberofEachFiber

1.3 ADVANTAGESOFHYBRIDFIBERREINFORCEDCONCRETE

1. **Crack Bridging at two stages is carried out:** As two types of fibers are used, one willtreat the initial micro cracks. Further chances of macro cracks are treated by next type offibers.This is not achieved byasingle typeoffiber.
2. **Two or more types of system:** One type provides strength and stiffness. The other typewillgain flexibilityandductility.
3. It can use fiber with different durability.

1.2. APPLICATIONSOFHYBRIDFIBERREINFORCEDCONCRETE

- Hybrid Fiber Reinforcement in ConcretePavements
- Rehabilitation of Bridge Deck Using HybridFiber Reinforced Concrete
- Construction of machine foundation:
- Tunnel Linings

1.3. SCOPEANDOBJECTIVES OFWORK

1. Tostudythe propertiesof glassfibersand steelfibers.
2. Tostudythebehaviour of concreteunder various%of additionoffibers
3. Tocomparethestrength parametersofhybridconcretewithconventionalconcrete.
4. The main aim regarding the tensile strength of hybrid fiber reinforced concrete is to attainmaximumtensilestrength at minimum use offibers.
5. Tofindtheoptimum percentageofhybridfibers.

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II. LITERATURE REVIEW

2.1 REVIEWONSFRC

AbdulGhaffar,AmirS Chauhan, Dr. R S Tatwawadi[1]

Their research is based on the investigation of steel fiber in structural concrete to enhance themechanical properties of concrete. They have conducted compression and flexural strengthtest on the concrete. An eleven mix batches of concrete containing 0% to 5% with interval of0.5% by weight of cement. The type of steel fiber used is Hooked steel fiber and the grade ofconcrete is M35. The compressive strength for addition of 3% gives the maximum value and4%of fiber gives maximum flexural strength.

Milind V Mohod[6]

In this paper the effect of fibers on the strength of concrete for M30 grade have been studiedby varying percentage of fibers by 0.25%, 0.50%, 0.75%, 1%, 1.5% and 2% by volume ofconcrete. The type of fiber used is Hooked steel fiber. Addition of 1% of steel fiber givesmaximumcompressivestrength and0.75%fibergivesmaximum flexuralstrength.

VasudevR,Dr.B G Vishuram[7]

The investigation is done on M20 and M30 grade of SFRC by varying the percentage of steelfibers from 0.25%, 0.5%, 0.75% and 1% to the volume of concrete. For M20 grade, themaximum strength is obtained at 0.5% of fiber added to the volume of concrete. For M30grade,themaximum strengthisobtained at1% of fiberadded tothevolumeofconcrete.

2.2 REVIEWONGFRC

B.Prasanti, N VidyaSagar[4]

In this experimental investigation the glass fiber in addition percentage from 0 to 0.09%, i.e.0%, 0.03%, 0.06%, and 0.09% is added and studied for the effect on mechanical properties tocompressive strength and stress strain behavior of M20 and M40 grade. The type of fiberused is Alkali resistance glass fiber. 0.09% of fiber gives maximum compressive strength forM20and M40 gradeof concrete.

Md.Abid Alam,ImranAhmad,FazlurReham[5]

In this study the alkali resistance glass fiber is used. A total of 8 mixes were prepared byvaryingpercentageofglassfiberforM20andM30gradeofconcrete.Thepercentageofglassfibersarevariedby 0,0.02%,0.04%,0,06%tothevolumeofconcrete0.06% gavethemaximumcompression and tensilestrengthin both the gradeofconcrete.

AUpendraVerma,A DKumar[3]

Inthisexperimentalstudythetestisconducted ondifferentgradesofconcretei.e.M20,M30,M40 and M60 by addition of 0% to 0.03% of glass fiber to the volume of concrete. The typeof fiber used is Cem-fil-anti crack glass fiber. For M20 grade, the compressive strength isincreased by 13.52%. Split tensile is increased by 16.23%. For M30 grade, the compressivestrengthis increased by17.43%and flexural strength is increased by17.71%.

III. MATERIALS AND PROPERTIES

3.1. CEMENT

Cement is a material that has cohesive and adhesive properties in the presence of water. Suchcements are called hydraulic cements Therearedifferenttypesofcement;wehavemadeuseof Ordinary Portland Cement to carry out this research work. Portland cement is the mostcommon type of cement in general used around the world, used as a basic ingredient ofconcrete, mortar, and most non-specialty grout. It developed from other types of hydrauliclime in England in the mid-19th century and usually originates from limestone several types of Portland cement areavailable with the most common being called Ordinary Portland Cement (OPC) which isgreenishin colour, but a white Portland cement isalsoavailable. Thetypeof cementusedin thisprojectworkis BirlasuperCement(53-gradeOPC)

Table.1 Physical properties of cement

SL.NO	PROPERTIES	OBTAINED VALUES
1	Fineness	4%
2	Initial setting time	120min
3	Standard consistency	33%
4	Specific gravity	3.12
5	Final setting time	580 min

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3.2. FINEAGGREGATES

Fine aggregate is material passing through an IS sievethat is less than 4.75mm gauge beyondwhich they are known as coarse aggregate. Themostimportant function of the fine aggregate is to provide workability and uniformity in themixture. The fine aggregate also helps the cement paste to hold the coarse aggregate particlein suspension. According to IS 383:1970 the fine aggregate is being classified in to fourdifferent zones, that is Zone-I, Zone-II, Zone-III, Zone-IV. Also, in case of coarse aggregatemaximum 20 mm coarse aggregate is suitable for concrete work. But where there is norestriction40mmorlargesizemaybepermitted. In caseofclosereinforcement10mmsizeisalso used.

Table.2 Physical properties of Fine aggregate

SL NO	PROPERTIES	VALUE
01	Fineness modulus	2.39
02	Specific gravity	2.63

3.3. COARSEAGGREGATES:

Coarse aggregates are particles greater than 4.75mm in size. They can either be fromPrimary, Secondary or Recycled sources. Primary, or 'virgin', aggregates are either Land- orMarine-Won. Gravel is a coarse marine-won aggregate; land-won coarse aggregates includegravel and crushed rock. Gravels constitute the majority of coarse aggregate used inconcretewith crushedstonemakingup most of theremainder.

Table. 3 Physical properties of Coarse Aggregate

SL NO	PROPERTIES	VALUES
01	Fineness modulus	7.35
02	Specific gravity	2.72
03	Water absorption	0.7%

3.4. ADMIXTURES

Admixtures are materials other than cement aggregate and water that are added toconcrete either before or during its mixing to alter its properties. It is used as an ingredient ofconcreteor mortar addedto thebatch immediatelybeforeor duringmixing.
Therearetwo kindsof admixtures:

- Chemicaladmixtures
- Mineraladmixtures

3.4.1. Chemicalcomposition:

The raw material used for the manufacture of cement consists mainly of lime, silica aluminaand iron oxide. These oxides interact with one another in the kiln at high temperature to formmorecomplexcompound.Therelativeproportions oftheseoxidecompositionsareresponsibleforinfluencingthevariouspropertiesofcement;inadditiontorateofcoolingandfinenessofgrinding.

3.4.2 SUPERPLASTICIZERS

Super plasticizers, also known as high range water reducers, are chemical admixtures usedwhere well dispersed particle suspension is required. These polymers are used as dispersantstoavoidparticlesegregation(gravel,coarseandfinesands),andtoimprovetheflowcharacteristics suspensions such as in concrete applications. Their addition to concrete ormortar allows the reduction of the water-cement ratio, not affecting the workability of themixture, and enables the production of self-consolidating concrete and high-performanceconcrete. This effect drastically improves the performance of the hardening fresh paste.
Thestrengthofconcreteincreaseswhenthewater-cementratiodecreases.However,theirworkingmechanisms lack a full understanding, revealing in certain cases cement-superplasticizerincompatibilities. The addition of superplasticizer in the truck during transit is a fairly newdevelopmentwithin theindustry. In the study, Master Glenium Sky 8233 is used as super plasticizer.

3.4.3.BENEFITSOFMASTERGLENIUMSKY8233

- Eliminationofvibrationandreducedlabourcostinplacing.
- Markedincreaseinearlyandultimatestrengths.
- HigherEmodulus.
- Improvedadhesiontoreinforcingandstressingstee

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- Better resistancetocarbonationandotheradverseatmospshericconditions
- Lowerpermeability-increaseddurability
- Reducedshrinkageandcreep

3.4.4.**FIBERS**
STEELFIBER

The type of steel fiber used is Hooked end steel fiber. It is manufactured by quality base steelbar, characterized by high tensile strength. Thus, the average tensile strength of the steel fiber1100 MPa. Owing to its high strength and uniform distribution of fibers, stresses can be fullydispersedandcrackingpropagation beeffectively controlled.

GLASSFIBER

The glass fiber used are of Anti-crack HD referred as Alkali resistance glass fiber. From themicro to the macro fiber range, these fibers control the cracking processes that can take placeduringthelifespanofconcrete.

IV. MIX DESIGN

Mix design is done for M40 grade of concrete as per IS standard specification (IS 10262 –2009)andIS 456:2000.

4.1. **Objectivesofconcretemixdesign:**

- Toachieveaspecifiedcompressivestrengthfora specifiedgrade.
- Tomaintainworkabilityofconcretemixthroughoutwork.
- Forachievingdurability.
- Toachieve economybyselectingappropriate concreteingredients.
- Toobtainmaximumpossible yieldperbagofcement.
- Toavoid honeycombing andbleeding.
- Tocomplywith various standards.
- Toreducewastageofconcretebycorrectproportioning.

4.2. **MIXDESIGN**
Mix proportioningforaconcreteofM40grade

STIPULATIONSFORPROPORTIONING

a) Gradedesignation:M40
b) Typeofcement:OPC53Grade conformingIS12269
c) Maximum nominal sizeofaggregate : 20 mm
d) Minimumcementcontent:320 kg/m^3(IS456:2000)
e) Maximumwater-cementratio:0.45(Table5ofIS456:2000)
f) Workability:100-120mm slump
g) Exposurecondition:severe(ForReinforcedConcrete)
h) Methodofconcreteplacing:Handcompaction
j) Degreeofsupervision :Good
k) Typeofaggregate:CrushedAngularAggregates
m) Maximumcement content: 360kg/m^3
n) Chemicaladmixturetype :SuperplasticizerMaster GleniumSKY8233

4.3. **TESTDATAFORMATERIALS**
Cement used: OPC 53 Grade conforming IS 12269
1.Specific gravityofcement: 3.12
2.Specific gravity of coarse aggregate 20 mm: 2.72
3.Specific gravityofFine aggregate: 2.67
4. Specific gravityChemicaladmixture(SuperPlasticizerMaster GleniumSKY8233):1.09
Coarse aggregate: Conforming to all in aggregates of Table 2 of IS 383Fineaggregate:ConformingtoGradingZone IIof Table 4ofIS383

4.4. **MIX PROPORTION**
Cement = 350kg/m^3
Water = 140kg/m^3
Fine aggregate = 753kg/m^3
Coarse aggregate 20 mm = 1252kg/m^3
Chemical admixture = 5.25 kg/m^3
Water -content ratio =0.4
In other words **1:2.15:3.52,** which is in the order of Cement: fine aggregate: coarse aggregate.

MIX PROPORTION		
WATER CEMENT RATIO	0.4	0.4
CEMENT	340kg	1
FINE AGGREGATE	753kg	2.15
COARSE AGGREGATE	1252kg	3.57

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V. TESTS ON FRESH CONCRETE

Beforecastingthecubesandcylindersthetests onfreshconcretearetobeconductedtocheckmore importantly the flow of the concrete that is prepared and to confirm whether it is withinthe limits as mentioned in the guidelines or not. Also, the other tests are conducted to checkthe fillingand passingabilityofConcrete.
Therefore, the tests that are being conducted in this research work on fresh self-compactingconcreteare:

- **THE SLUMP TEST:-** To determine the consistency of concrete where thenominalsizeof theaggregateis>20mm
- **THE COMPACTING FACTOR TEST** - It is useful for concrete mixes of lowandmediumworkability
- **THE VEE BEE CONSISTENCY TEST** - To determine the time required fortransforming

RESULT ON SLUMP TEST:

Test	0% &0%	1% &0.06%	2% &0.09%
Slump test	120mm	116mm	110mm

RESULTONCOMPACTIONFACTOR TEST:

Test	0%& 0%	1%&0.06%	2%&0.09%
Compactingfactortest	0.93	0.92	0.89

CompactionFactorValue=(W1-W)/(W2-W)

RESULT ON VEE-BEE CONSISTOMETER TEST:

TEST	0% &0%	1% &0.06%	2% &0.09%
Vee-beeConsistencytest	3secs	9secs	12secs

5.1.CASTING AND CURING MOULD PREPARATION:

Mould is cleaned properly and greased with mould oil. Concrete is placed in the mould ofdimension 150mm x 150mm x 150mm in 3 layers each layer of height approximately 50mmafter the placement of first layer of concrete it is compacted by a tamping rod of 16mmdiameter, 0.6m long and bullet pointed at the lower end. The strokes of the bar are uniformlydistributed over the cross section of the mould. Each layer is compacted with 25 strokes andcoconutshellsaresprinkleduniformlyoneachlayer, nextscoopofconcreteisplacedfollowedbysamemanner of compaction and top layer is finished.

5.2. CURINGOFSPECIMENS:

Thetestspecimensarestoredinplacefreefromvibration, inmoistairofatleast90%relativehumidityandatatemperatureof27o+2o Cfor24 hoursfromthetimeofadditionofwatertothedryingredients.

VI. TESTS ON HARD ENED CONCRETE

6.1. COMPRESSIVESTRENGTHTEST:

Compression test is the most common test conducted on hardened concrete, partlybecause is an easy test to perform, and partly because most of the desirable characteristicproperties of concrete are qualitatively related to its compressive strength. The of the size150×150x150 mm. Metal moulds, preferably steel or cast iron, thick enough to preventdistortion are required. Compression test develops a rather more complex system of stresses.Due to compression load, the cube undergoes lateral expansion owing to the Poisson's ratioeffect. Compressive strength test usually gives an overall picture of the quality of concretebecausestrengthisdirectlyrelatedtothestructureofthehydratedcementpaste.Thecompression test is an important concrete test to determine the strength development of theconcrete specimens. Compressive strength tests are to be performed on the cube specimens attheages of 7and 28days.
Compressivestrength=Load/AreaN/mm^2

RESULTS AND DISCUSSION

TABLE6.1Compressivestrengthafter 7, 14 and 28 days of curing

Specimen	% of SF	% of GF	7days strength N/mm^2	14days strength N/mm^2	28days strength N/mm^2
01	0	0	38.773	47.836	51.923
	1	0.66	44.964	59.926	67.527
	2	0.69	50.232	64.010	71.303

TABLE6.2FLEXURALSTRENGTHRESULTS

Specimen	% of SF	% of GF	7days strength N/mm^2	14days strength N/mm^2	28days strength N/mm^2
01	0	0	3.884	4.292	5.172
	1	0.66	4.634	4.956	5.910
	2	0.69	5.363	5.866	6.766

TABLE6.3SPLITTENSILESTRENGTHRESULTS

Specimen	% of SF	% of GF	7days strength N/mm^2	14days strength N/mm^2	28days strength N/mm^2
01	0	0	2.366	2.558	2.905
	1	0.66	3.000	3.450	4.260
	2	0.69	3.803	4.343	5.543

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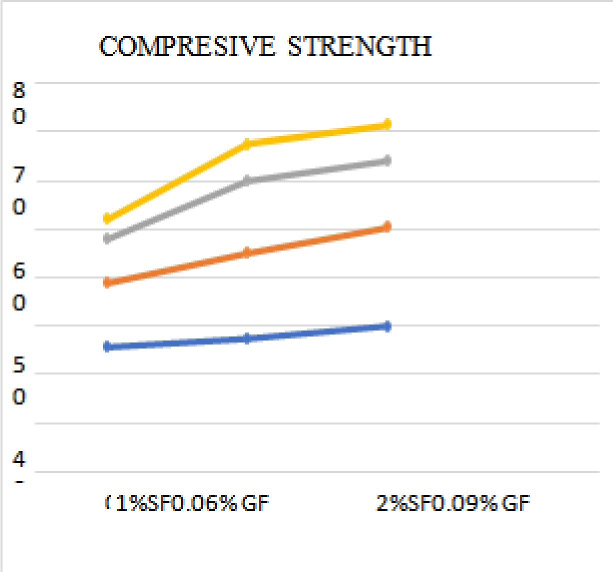

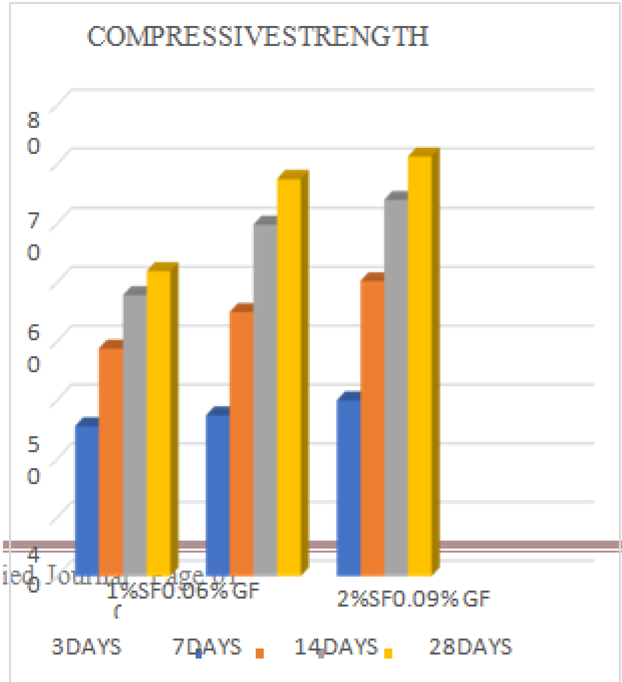

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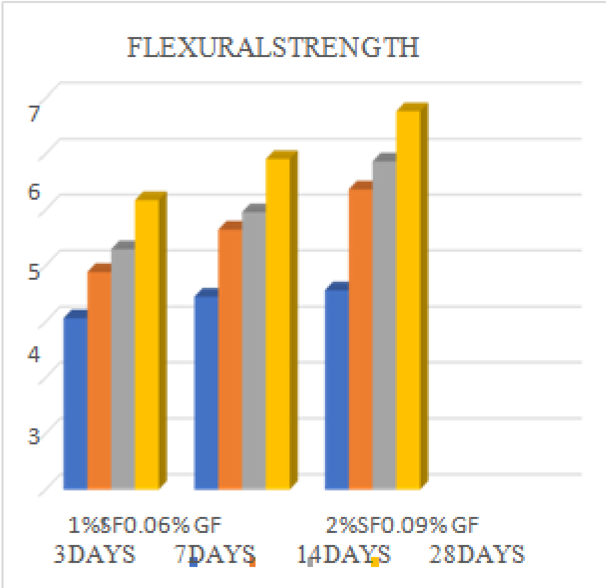

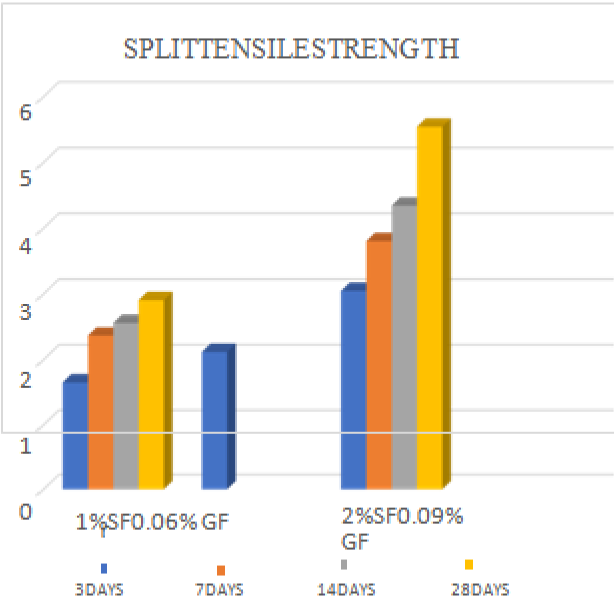

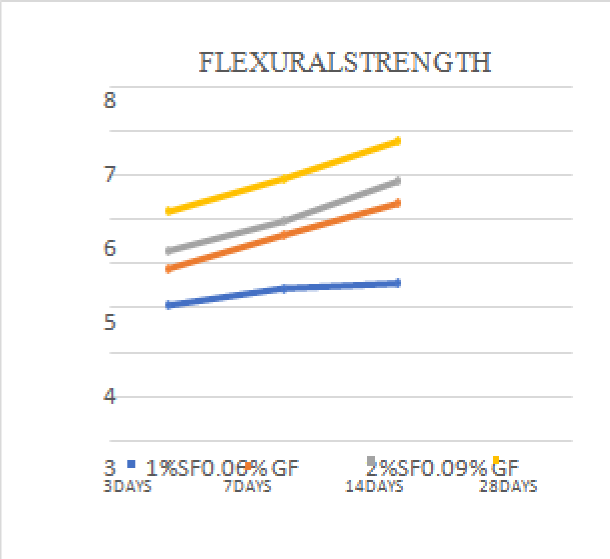

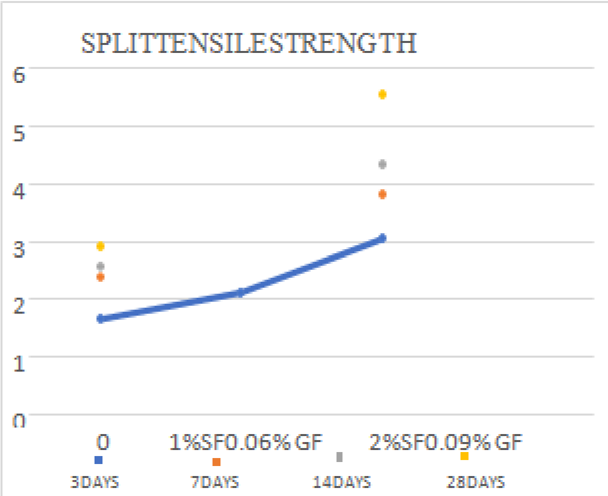

VII. CONCLUSION

- The addition of steel fiber and glass fiber results in increase of 15.73% compressivestrength,13.35% increase in flexural strengthand26.51%increaseinsplit tensilestrength.
- Addition of 2% of steel fiber and 0.09% of glass fiber gives maximum compressivestrength of 71.303 N/mm2 , Tensile strength of 5 N/mm2 and Flexure strength of 6.766N/mm2
- The rate of strength gain for 7 days strength of HFRC is very high as compared toconventional concrete and hence concludes that HFRC has high early Strength and continuedstrengthdevelopment.
- Asthepercentageoffibersincreasesthesplittensile strengthalsoincreases.
- Workabilitydrasticallydecreases when the fiber content is increased inconcrete.
- The improved mechanical properties of HFRC would result in reduction of warpingstresses,short and longterm crackingand reduction ofSlabthickness.

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