Strength Characteristics of Hybrid Fibre Reinforced Concrete using Nano Silica

Hybrid Fibre Reinforced Concrete

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Abstract—HybridFiberReinforcedConcrete (HFRC)is formedfromacombination ofdifferenttypesoffibres,which differinmaterial properties,remain bondedtogetherwhen addedinconcreteandretaintheiridentitiesandproperties. Thecombining offibers,oftencalledhybridization,is investigatedforaM60gradeconcreteatavolumefractionof 4%NanoSilca,Steel fiber(1,1.25,1.5%)andpolypropylene fiber(0.03,0.06,0.09%)inthisproject.Control andfourhybrid fibercomposites werecastusingdifferentfiberproportionsof steelandpolypropylene.Compressive strength,splittensile strengthandflexuralstrengthtest wereperformedandresults wereanalyzedtoassociatewithabove fibercombinations. Basedonexperimental studies,theprojectidentifiesfiber combinations thatdemonstrate maximumcompressive,split tensile andflexuralstrengthofconcrete.Inadditiontothe above,SEM imagesarepresented.

Keywords—Fibre,Concrete,HybridFibre,NanoSilica

INTRODUCTION

Acompositecan betermedashybrid, iftwoormoretypesoffibresarerationallycombined ina commonmatrixtoproduceacomposite thatdrivesbenefits fromeachoftheindividual's fibresandexhibitsasynergetic response.Additionofshortdiscontinuous fibresplaysan importantroleintheimprovementofmechanicalpropertiesof Concrete.Itincreaseselasticmodulus; decreasesbrittleness controls cracksinitiationanditssubsequentgrowthand propagation. Deboningandpull outofthefibrerequiremore energyabsorption,resulting inasubstantial increaseinthe toughnessandfractureresistance ofthematerialstothe cyclic anddynamicloads.

A. HistoryofHFRC

The concept of using fibres as reinforcement is not new. Fibreshavebeenusedasreinforcementsinceancient times. Historically,horsehairwasusedinmortar andstrawinmud bricks.Intheearly 1900s,asbestos fibreswereusedin concrete,therewasaneedtofindareplacement forthe asbestos used inthe concreteandotherbuildingmaterialsonce thehealth risksassociatedwiththesubstance werediscovered. Bythe 1960s,steel, glass,andsynthetic fibressuchas polypropylenefibreswereusedinconcrete, andresearchinto newfibre reinforced concretescontinuestoday.

B. AdvantagesofHybridFibreReinforcedConcrete

1)Toprovide asysteminwhichone typeoffibre,thisis stronger and stiffer, improves the first cracks stress and ultimatestrength,andthesecondtypesoffibre,whichismore flexible,andductile leadstoimprovedtoughnessandstainin thepastcrackingzone.

2)To provide hybridreinforcement inwhichone typeoffibre issmaller, sothatitbridgesthemicrocracksofwhichgrowth canbecontrolled. Thisleadstoahighertensile strengthofthe composite. Thesecondtypeoffibreislarger,sothatitarrests thepropagatingmicrocracksandcansubstantiallyimprove thetoughnessofthecomposite.

3)Toprovideahybridreinforcement,inwhichthedurability offibretypeisdifferent.Thepresenceofthe durablefibrecan increasethestrength andtoughnessrelation after age whilethe othertypeistoguaranteetheshorttermperformance during transportationandinstallationofthecompositeelements.

C. ApplicationofHybrid FibreReinforcedConcrete

HFRCcanbeusedinanykindofconstruction becauseofits unique Propertiesandalsoasitveryeasytoobtainhighrange ofstrengthvalues.Someofthepioneeringapplications areas follows

- Bridges.
- Tunnellinings.
- Buildingcomponentslikecolumn.
- Sandwichstructurelikesteelconcretestructure.

Thebenefitofhybridfibresinenhancing variouspropertiesof theHFRCinadditiontoNanosilicahasnotbeeninvestigated inthepast andhencetheeffectofhybridfibrescomprising of steel, PP fibres and Nano silica in the HFRC on the mechanical properties and flexural toughness of HFRC is beingexploredinthisresearch.Thus,themainobjectiveof thisstudyistoinvestigate theeffectofsteel-PPhybridfibres andNanosilicainenhancing themechanicalproperties, flexuralstrengthofHybridFibre Reinforced Concrete(HFRC).

MATERIALPROPERTIES

A. Sieve analysistestfor Fineaggregate

Sieve Size	Weight Retained (gms)	Cumulative weight retained	Cumulative % weight retained	% Finer
4.75mm	26	26	2.6	97.4
2.36mm	64	90	9.0	91
1.18mm	177	267	26.7	73.3
600µ	260	527	52.7	47.3
300µ	385	912	91.2	8.8
150µ	50	962	96.2	3.8
Pan	38	1000	100	0

Finenessmodulusofthefine aggregate= F/100

= 378.4 /100=3.78

FromIS:383-1970, Table4 (Pg no:11),FineAggregates,

Grading Zone = II

B. SpecificGravityofFineAggregate

W_1= 660 g W_2 = 1858g W_3 = 2090g W_4 = 1365g

Hence, SpecificGravity = 2.43

C. Sieveanalysistest forCoarseaggregate

ISSieve Size	Weight retained	% Weight retained	%Weight passing	Cumulative Weight retained
80mm	0	0	100	0
40mm	0	0	100	0
20mm	1.86	37.2	62.8	37.2
10mm	1.62	32.4	67.6	69.6
4.75mm	1.52	30.4	69.6	100
2.36mm	0	0	100	100
1.18mm	0	0	100	100
600µ	0	0	100	100
300µ	0	0	100	100
150µ	0	0	100	100

Finenessmodulusofthecoarse aggregate= F/100

= 7.06

D. Specificgravityof coarseaggregate

Emptyweightofthe container (A) = 3.59 kg

Container+coarse aggregate (B) =7.09 kg

Container+coarse aggregate+ water (C) =8.38 kg

Container+water (D) = 6.1 kg

Specificgravity = B-A/[(B-A)-(C-D)]

Thespecific gravityofthe coarseaggregate is2.87

E. WaterAbsorption TestforCoarseAggregate

1)Weightof emptybasket =572gms

2)Weightofbasket+gravel=1472gms

3)Weightofbasket+wetgravel =1484gms

4)Weightofbasket+drygravel =1472gms

CALCULATION

Ww= (w2-w3)= (1484-1472)

=12

Ws= (w3-w1)=(1472-572)

=900

W= (Ww/ws)=(12/900)

=0.010

Waterabsorption = 1.0%

F. Specificgravity ofcement

Emptyweightoftheflask W1=0.131 kg

Borosil+ water W2= 0. 368 kg

Borosil+ kerosene W3=0.318 kg

Borosil+ kerosene+ cement W4=0.364 kg

Emptyweightofthecement W5= 0.060 kg

g =W3-W1/W2-W1

=0.789

G =W5/ (W5+W3-W4)× g =3.14.

G. FinenessofCement

ISSieve	Weight retained(gms)	%Weight retained	%Finer
90µ	4	4	96
Pan	96	96	4

% Finer= 4%

H. Consistency ofCement

Water%	Water content	Readingin plunger
24%	81.6	32
26%	88.4	26
28%	95.2	22
30%	102	18
32%	108.8	16
34%	115.6	5

Consistencylimit= 34%

I. SteelFibre

Type:Hookedendsteelfibre

AspectRatio= 50/1= 50

Steelfibre

J. PolypropyleneFibre

Polypropylenefibre

K. PropertiesofNano silica

Testitem	Standard requirements	TestResults
Specific Surface Area (M2/G)	200 +20	202
pH Value	3.7 – 4.5	4. 12
Loss on Drying@105 DEG.C(5)	<1.5	0. 47
SieveResidue(5)	<0.04	0. 02
TampedDensityg/L	40 – 60	44
Si Content(%)	>99. 8	99. 88
CARBON CONTENT(%)	<0.15	0. 06
Chloride Content (%)	<0.0202	0. 009
	<0.03	0. 005
Ti	<0. 02	0. 004
	<0. 003	0. 001
ParticleSize	17 NANO	

ACI MIXDESIGN

The most common method used in North America is thatestablishedby**ACI RecommendedPractice211.1**

5.1.2 Calculation

1) Select theslumpandrequiredconcretestrength

$$f_{cr} = \frac{8702.2+1400}{0.9} = 11224.75 \text{ Psi}$$

$[1\ Mpa = 145.02\ Psi]$;

= 77.4 Mpa

2) Select themax sizeofaggregate¾ inch (or)19mm

3) Selecttheoptimumcoarse aggregate

0.67*101* 27 = 1826.3 lb/

$[1 lb/yd^3 = 0.59$;

=1083 kg/

4) TakeWatercementratioas0.3

5) Weightof cement

AsperACI211.1Clause6.3.3pgno.8Select approx.mixingwaterandairrequirementis265lb/ yd^3

Weightofcement= $\frac{265}{0.3}$ =885.33lb/yd^3 =525 kg/m^3

6) Volumeof coarse aggregate

As perACI211.1-91 Table6.3.6

For¾inchsizedaggregate&Finenessmodulusof Fine aggregate3.78 valueis0.64

Coarse aggregatewilloccupy

0.64*27 =18.26ft^3/yd^3

TheODweightofCoarseaggregate,

18.26*100 =1826.26 lb/ yd^3

7)Proportionbasicmixturewith cementonly

Cement= =4.503

Coarse Aggregate= = 10.19

Water= =4.25

Air= 0.02* 27 =0.54

19.48

27-19.48 = 7.52

7.52*62.4*2.43 =1140.27 lb/

	lb/	kg/
Cement	885.33	525
Fine aggregate	1140.27	676
Coarseaggregate	1826	1083

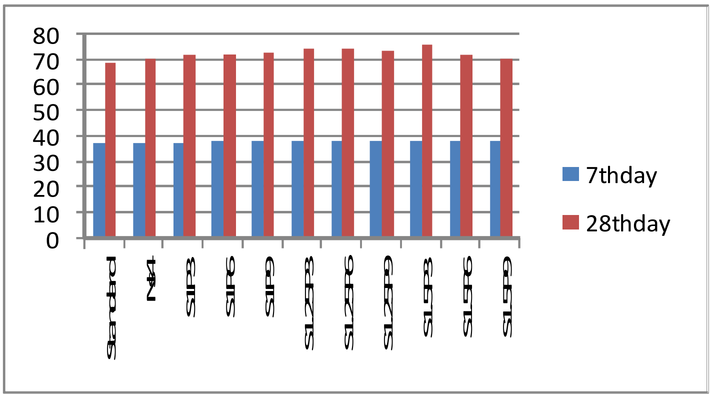
Hence,**the ratiois1:1.287:1.948**

RESULTSANDDISCUSSION

COMPRESSIVESTRENGTHOFCONCRETE

- TheCompressivestrengthofConventionalconcrete on7th dayis37.86Mpaanditisincreased54.95%on 28thday.
- InadditiontoNanosilica4%totheConventional, thecompressivestrengthon7th dayis37.83Mpaand itisincreased53.31%on28th day.Ascomparedto conventional concrete,CompressiveStrength increased 3.09%on 28thday.
- The hybridfibrecompositioninadditionto(1%Steel Fibre–0.015%PolypropyleneFibre)inadditionto 4%Nanosilica,thecompressionstrengthofconcrete at the age of 7 days 37.92Mpa. It was increased 4.51%comparedtoconventionalconcreteattheage of28 daysrespectively.
- Thehybrid fibre compositionin additionto (1% Steel Fibre –0.03%Polypropylene Fibre)inaddition to4%Nanosilica,the compressionstrengthof concrete attheageof7days38.1Mpa.Itwas increased5.37%comparedtoconventionalconcrete atthe ageof28 daysrespectively.
- The hybridfibrecompositioninadditionto(1%Steel Fibre–0.04%PolypropyleneFibre)inadditionto 4%Nanosilica,thecompressionstrengthofconcrete at the age of 7 days 38.07Mpa. It was increased 6.34%comparedtoconventionalconcreteattheage of28 daysrespectively.
- Thehybridfibrecompositioninadditionto(1.25% Steel Fibre – 0.015% Polypropylene Fibre) in addition to4%Nanosilica,thecompression strength ofconcrete attheageof7days38.6Mpa.Itwas increased7.74%comparedtoconventionalconcrete atthe ageof28 daysrespectively.
- Thehybridfibrecompositioninadditionto(1.25% Steel Fibre –0.03%Polypropylene Fibre)inaddition to4%Nanosilica,the compressionstrengthof concrete attheageof7days38.54Mpa.Itwas increased8.17%comparedtoconventionalconcrete atthe ageof28 daysrespectively.
- Thehybridfibrecompositioninadditionto(1.25% Steel Fibre –0.04%Polypropylene Fibre)inaddition to4%Nanosilica,the compressionstrengthof concrete at the age of 7 days 38.57Mpa. It was increased7.09%comparedtoconventionalconcrete attheageof28 daysrespectively.
- Thehybridfibrecompositioninadditionto(1.5% Steel Fibre – 0.015% Polypropylene Fibre)in addition to4%Nanosilica,thecompressionstrength ofconcrete attheageof7days38.78Mpa.Itwas increased10.1%comparedtoconventionalconcrete attheageof28 daysrespectively.
- Thehybridfibrecompositioninadditionto(1.5% Steel Fibre–0.03%PolypropyleneFibre)in addition to4%Nanosilica,thecompression strengthof concrete attheageof7days38.66Mpa.Itwas decreased3.95%comparedtoconventionalconcrete attheageof28 daysrespectively.
- Thehybridfibrecompositioninadditionto(1.5% Steel Fibre–0.04%PolypropyleneFibre)in addition to4%Nanosilica,thecompression strengthof concrete attheageof7days38.78Mpa.Itwas decreased5.93%comparedtoconventionalconcrete attheageof28 daysrespectively.

Fig. Compressivestrengthofconcrete



SPLITTINGTENSILESTRENGTHOFCONCRETE

- The Splitting tensile strength of Conventional concreteon7th dayis4.29Mpaanditisincreased 6.98%on 28thday.
- InadditionofNanosilica4%totheConventional, the Splitting tensile strengthon7th dayis4.2Mpaand itisincreased67.52%on28th day.Ascomparedto conventional concrete,SplittingtensileStrength increased1.5%on 28thday.
- Thehybridfibrecompositioninadditionto(1% Steel Fibre–0.015%PolypropyleneFibre)inadditionto 4% Nano silica, the splitting tensile strength of concrete at the age of 7 days 4.26Mpa. It was

increased4.4%comparedtoconventional concreteat theageof28 daysrespectively.

- The hybridfibrecompositioninadditionto(1%Steel Fibre–0.03%PolypropyleneFibre)inadditionto 4%Nanosilica,the Splitting tensile strengthof concrete attheageof7days4.35Mpa.Itwas increased4.88%comparedtoconventionalconcrete atthe ageof28 daysrespectively.

- The hybridfibrecompositioninadditionto(1%Steel Fibre–0.04%PolypropyleneFibre)inadditionto 4% Nano silica, the splitting tensile strength of concrete at the age of 7 days 4.41Mpa. It was increased5.37%comparedtoconventionalconcrete atthe ageof28 daysrespectively.

- Thehybridfibrecompositioninadditionto(1.25%Steel Fibre – 0.015% Polypropylene Fibre) in addition to4%Nanosilica,thesplitting tensile strengthofconcreteattheageof7days4.5Mpa.It wasincreased6.82%compared toconventional concreteattheageof28 daysrespectively.

- Thehybridfibrecompositioninadditionto(1.25% Steel Fibre –0.03%Polypropylene Fibre)inaddition to4%Nanosilica,thesplittingtensile strengthof concrete attheageof7days4.56Mpa.Itwas increased7.78%comparedtoconventionalconcrete atthe ageof28 daysrespectively.

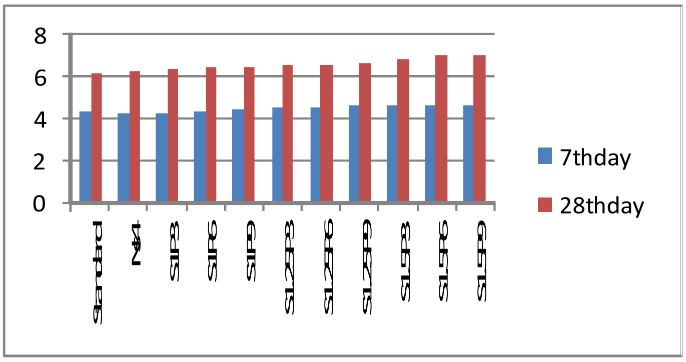
- Thehybridfibrecompositioninadditionto(1.25% Steel Fibre –0.04%Polypropylene Fibre)inaddition to4%Nanosilica,thesplittingtensile strengthof concrete attheageof7days4.59Mpa.Itwas increased8.27%comparedtoconventionalconcrete atthe ageof28 daysrespectively.

- Thehybridfibrecompositioninadditionto(1.5% Steel Fibre – 0.015% Polypropylene Fibre) in addition to4%Nanosilica,thesplitting tensile strengthofconcrete attheageof7days4.64Mpa.It wasincreased11.17%compared toconventional concreteattheageof28 daysrespectively.

- Thehybridfibrecompositioninadditionto(1.5% Steel Fibre –0.03%Polypropylene Fibre)inaddition to4%Nanosilica,thesplittingtensile strengthof concrete attheageof7days4.65Mpa.Itwas increased14.07%comparedtoconventional concrete atthe ageof28 daysrespectively.

- The hybridfibrecompositioninadditionto(1%Steel Fibre–0.04%PolypropyleneFibre)inadditionto 4%Nanosilica,thesplitting tensilestrengthof concrete attheageof7days4.67Mpa.Itwas increased15.52%comparedtoconventionalconcrete attheageof28 daysrespectively.

Fig. Splittingtensilestrengthof concrete



FLEXURALSTRENGTHOFCONCRETE

- TheFlexuralstrengthofConventionalconcreteon 7th dayis2.75Mpaanditisincreased51.69%on28th day.

- InadditionofNanosilica4%totheConventional, the Flexuralstrengthon7th dayis2.875Mpaanditis increased 51.16%on28th day.Ascompared to conventional concrete, Flexural Strength increased 5.63%on 28thday.

- Thehybridfibrecompositioninadditionto(1% Steel Fibre–0.015%PolypropyleneFibre)inadditionto 4%Nanosilica,theflexuralstrengthofconcreteat the ageof7days3.22Mpa.Itwasincreased22.06% comparedtoconventionalconcreteattheageof28 daysrespectively.

- Thehybridfibrecompositioninadditionto(1% Steel Fibre–0.03%PolypropyleneFibre)inadditionto 4%Nanosilica,theflexuralstrengthofconcreteat the ageof7days3.25Mpa.Itwasincreased25.35% comparedtoconventionalconcreteattheageof28 daysrespectively.

- Thehybridfibrecompositioninadditionto(1% Steel Fibre–0.04%PolypropyleneFibre)inadditionto 4%Nanosilica,theflexuralstrengthofconcreteat the ageof7days3.27Mpa.Itwasincreased26.76% comparedtoconventionalconcreteattheageof28 daysrespectively.

- Thehybridfibrecompositioninadditionto(1.25% Steel Fibre – 0.015% Polypropylene Fibre) in

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addition to4%Nanosilica,theflexuralstrengthof concrete attheageof7days3.45Mpa.Itwas increased35.21%comparedtoconventional concrete atthe ageof28 daysrespectively.

- Thehybridfibrecompositioninadditionto(1.25% Steel Fibre –0.03%Polypropylene Fibre)inaddition to4%Nanosilica,theflexuralstrengthofconcrete at theageof7days3.5Mpa.Itwasincreased37.08% comparedtoconventionalconcreteattheageof28 daysrespectively.

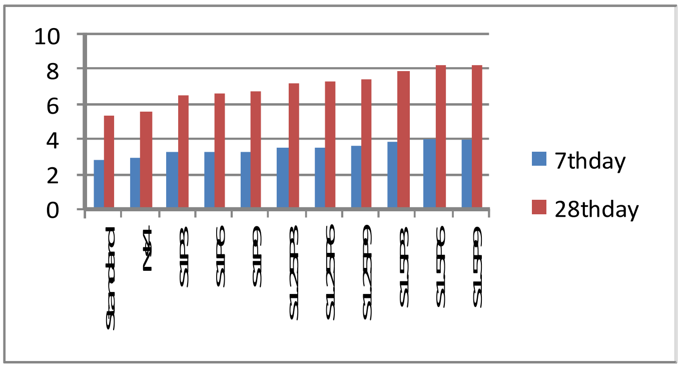
- Thehybridfibrecompositioninadditionto(1.25% Steel Fibre –0.04%Polypropylene Fibre)inaddition to4%Nanosilica,theflexuralstrengthofconcrete at the ageof7days3.55Mpa.Itwasincreased39.09% comparedtoconventionalconcreteattheageof28 daysrespectively.

- Thehybridfibrecompositioninadditionto(1.5% Steel Fibre – 0.015% Polypropylene Fibre) in addition to4%Nanosilica,theflexuralstrengthof concrete attheageof7days3.85Mpa.Itwas increased49.29%comparedtoconventional concrete atthe ageof28 daysrespectively.

- Thehybridfibrecompositioninadditionto(1.5% Steel Fibre –0.03%Polypropylene Fibre)inaddition to4%Nanosilica,theflexuralstrengthofconcrete at theageof7days3.9Mpa.Itwasincreased54.46% comparedtoconventionalconcreteattheageof28 daysrespectively.

- Thehybridfibrecompositioninadditionto(1.5% Steel Fibre –0.04%Polypropylene Fibre)inaddition to4%Nanosilica,theflexuralstrengthofconcrete at the ageof7days3.92Mpa.Itwasincreased55.86% comparedtoconventionalconcreteattheageof28 daysrespectively.

Fig. Flexuralstrengthofconcrete



CONCLUSION

COMPRESSIVESTRENGTH

- Compressivestrengthattainsmaximum atadditionof 4%of Nanosilica, 1.5%SteelFibresand0.01% Polypropylene fibrestotheM60 grade concrete.
- Thehybridfibrecompositioninadditionto(1.5% Steel Fibre – 0.015% Polypropylene Fibre)in addition to4%Nanosilica,thecompressionstrength ofconcrete attheageof7days38.78Mpa.Itwas increased10.1%comparedtoconventionalconcrete attheageof28 daysrespectively.

SPLITTINGTENSILESTRENGTH

- Splittingtensilestrengthattainsmaximumataddition of4%ofNanosilica,1.5%SteelFibresand0.04% Polypropylene fibrestotheM60 grade concrete.
- Thehybridfibrecompositioninadditionto(1% Steel Fibre–0.04%PolypropyleneFibre)inadditionto 4%Nanosilica,thesplitting tensilestrengthof concrete attheageof7days4.67Mpa.Itwas increased15.52%comparedtoconventionalconcrete attheageof28 daysrespectively.

FLEXURALSTRENGTH

- Flexuralstrengthattainsmaximumatadditionof4% of Nano silica, 1.5% Steel Fibres and 0.04% Polypropylene fibrestotheM60 grade concrete.
- Thehybridfibrecompositioninadditionto(1.5% Steel Fibre–0.04%PolypropyleneFibre)in addition to4%Nanosilica,theflexuralstrengthofconcrete at the ageof7days3.92Mpa.Itwasincreased55.86% comparedtoconventionalconcreteattheageof28 daysrespectively.

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