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STRUCTURAL BEHAVIOR OF HYBRID FIBER REINFORCED CONCRETE BEAM USING STEEL AND POLYVINYL ALCOHOL FIBER

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ABSTRACT

Fiber reinforcement is commonly used to provide toughness and ductility to cementitious matrix which is brittle in nature. Reinforcement of concrete with a single type of fiber may improve the desired properties of a composites to a limited level, whereas hybrid fiber is a combination of two or more types of fibers which are rationally combined to produce a composite that derives high benefits and exhibits a synergetic response. The aim of this investigation is to determine the addition of optimum dosage level of fibre in concrete. By having the optimum dosage level, beams are casted to determine the structural behaviour of HFRC. The hybrid fibers used are Steel Fiber (Crimped) in shape and PolyVinyl Alcohol Fiber. HFRC specimens are casted for 1% volume fraction. As a result of this investigation the structural performance such as ductility factor, stiffness and energy absorption capacity has significant improvement compared to conventional concrete.

Keywords: Hybrid Fiber Reinforced Concrete, PolyVinyl Alcohol fiber, Steel fiber, Ductility, Stiffness

INTRODUCTION

Hybrid Fiber Reinforced Concrete

Concrete as the most commonly used construction material, is developing towards high performance [12]. The performance of conventional concrete is enhanced by the addition of fibers in concrete.The incorporation of fibers into cementitious material has been proven to improve both their flexural toughness and resistance to crack development [4].Using a single type of fiber may improve the properties of fiber reinforced concrete to a limited level. However the concept of hybridization, that is the addition of two or more type of fiber in to concrete can offer more attractive engineering properties as the presence of one fiber enable more efficient utilization of the potential properties of the other fiber [5].The hybrid combination of metallic and non- metallic fibers can offer potential advantages in improving concrete properties as well as reducing the overall cost of concrete production. It is important to have combination of low and high modulus of fibers to arrest the micro and macro cracks respectively [3].

Steel Fiber

Steel fiber are filament of wire, deformed and cut to lengths, for reinforcement of concrete, mortar and other composite materials. Steel fiber has a considerably larger length and higher Young's modulus of elasticity as compared to the other fiber types. This led to an improved flexural rigidity and has great potential for crack control, although the volumetric density is high [2].

PolyVinyl Alcohol Fiber

These are synthetic fibers used in concrete to enhance their mechanical properties. The addition of non-metallic fibers results in good fresh concrete properties and reduces early age cracking. These small and soft fibers control crack initiation and propagation of small cracks [1]. Therefore this paper aims to determine the mechanical characteristics and structural behavior of hybrid fiber reinforced concrete mixed with two different types of fibers; steel fiber and PVA fiber in terms of compressive strength, splitting tensile strength, flexural strength, ductility factor, Stiffness, Energy absorption capacity and Energy index.

MATERIALS USED

Cement

Ordinary Portland cement of grade 53 was used for this study confirming to IS: 12269 - 1987 to cast the specimen. The physical properties of cement are presented in Table 1.

Table 1. Physical Properties of Cement

Name of the tests	Tested value
Standard consistency test	33%
Initial setting time	45 min
Final setting time	390 min
Strength test	54.08 N/mm^2
Specific gravity	3.1

Fine Aggregate

The concrete mixes were prepared by using clean dry river sand used as Fine aggregate and it is conformed to Zone III as per IS: 383 – 1970. The physical properties of fine aggregate are shown in Table 2.

Table 2. Physical Properties of Fine Aggregate

Name of the tests	Tested value
Fineness Modulus	2.56
Specific Gravity	2.65
Bulk Density (Kg/m^3)	1716.52

Coarse Aggregate

The blue granite stone was used as a coarse aggregate with a nominal maximum size of 20 mm is conformed to IS: 383 – 1970. The physical properties of coarse aggregate are shown in Table 3.

Table 3. Physical Properties of Coarse Aggregate

Name of the tests	Tested value
Water Absorption	1%
Specific Gravity	2.64
Fineness Modulus	3.85
Bulk Density (Kg/m^3)	1659.53

Water

According to IS 3025, water to be used for mixing and curing should be free from impurities. Potable water is generally satisfactory. In the present investigation locally available clean drinking water was used.

Super Plasticizer

Super plasticizers are selected based on IS 9013. In general efficient super plasticizers allow water reduction of at least 20% to 30% or more and also enhance slump retention. In this investigation Sulphonated Naphthalane is used.

Properties of Hybrid Fiber

The Properties of Steel and PolyVinylAlcohol fiber are shown in Table 4.

Table 4. Properties of Hybrid Fiber

Properties	Steel Fiber	PVA Fiber
Length (mm)	12.5	12
Diameter (mm)	0.5	0.1
Shape	Crimped	Straight
Type	Crimped	RECS 100
Aspect Ratio	25	120
Density (g/cm^3)	7.8	1.30
Tensile Strength (MPa)	1500	1200

EXPERIMENTATION

Concrete Mix Proportions

The mixes were designated in accordance with IS 10262-2009 mix design method. Based on the material properties results, the mix proportions M 30 was designed. Concrete mix with w/c ratio of 0.45 was prepared. The details of mix proportions for 1m3 of concrete are given in Table 5.

Table 5. Material required for 1m^3 of Concrete (Kg/m^3)

Grade	Cement	FA	CA	Water
M_{30}	352	716.64	1274.03	147.9

In this work, percentage of Hybrid fiber added by weight in concrete and the mix identification are shown in Table 6.

Table 6: Hybrid Fibre required for 1m^3 of concrete

S.No	Mix ID	Steel Fiber	PVA Fiber
1	HFRC 0	0	0
2	HFRC 1	0	1
3	HFRC 2	0.25	0.75
4	HFRC 3	0.50	0.50
5	HFRC 4	0.75	0.25
6	HFRC 5	1	0

4. Casting of test specimen

4.1 Casting of specimens for various strength

The experimental investigation was carried out on casting cube, cylinder and prism for both conventional concrete (HFRC 0) and Hybrid fiber reinforced concrete (HFRC 1-HFRC 5). A set of three samples for different percentage of concrete were casted and cured in water for 7 days and 28 days. The samples were taken from curing tank and dried for one hour before testing. The casted specimen sizes are listed in Table 7.

Table 7. Type of Casting the Specimen

S.No	Type of Specimen	Size of Specimen
1	Cube	150 x 150 x 150 mm
2	Cylinder	150mm in Diameter and 300 mm in Height
3	Prism	500 x 100 x 100 mm

4.2 Casting of Beam specimen for structural behaviour evaluation

The beam size of 1600 mm x180 mm x 110 mm was casted. Limit state method of design using IS 456:2000 was adopted for the design of beam and detailed as per IS13920:1993.The beam with 2 nos. of 16 mm diameter bar as tension reinforcement and compression reinforcement. The transverse reinforcement is provided with 8 mm diameter bars at 50 mm c/c near the end at a length of 325 mm as per IS 13920:1993 and after that provide 100mm c/c throughout. The reinforcement detailing of beam is shown in Fig. 1.

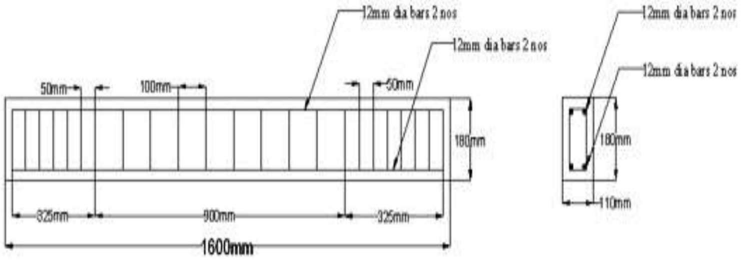

Fig 1. Reinforcement detailing of beam

Testing Procedure of Hybrid Fiber Reinforced Concrete

Compressive Strength Test

All cubes of conventional concrete and hybrid fiber reinforced concrete were tested in a compression testing machine with reference to IS 516-1959. From the compressive strength, the optimum percentage of hybrid fiber addition to the concrete is to be determined. All the specimens were tested under saturated surface dry condition.

Split Tensile Strength Test

All cylinders of conventional concrete and hybrid fiber reinforced concrete were tested in a compression testing machine with the reference to IS 516-1959 to determine the split tensile strength of concrete at 7 days and 28 days.

Flexural Strength Test

All the prism of conventional and hybrid fiber reinforced concrete were tested in compression testing machine with reference to IS 516 -1959 to determine flexural strength of concrete.

Experimental Set Up for Beam Specimen

The experimental setup for testing of beam specimen is shown in Fig. 2. The beam was supported on the two simply supported knife edges and tested in 100 T of Loading frame in Structural Engineering Laboratory. The load was gradually applied to the specimen by using hand operated hydraulic jack. The load was applied at an increment of 5kN up to the failure of specimen. The dial gauge was used to measure the deflection at mid-span. At each increment of loads, deflection and crack pattern were recorded. The failure mode of the specimen also observed.

Fig. 2. Test setup for Beam specimen

Test Results and Discussion of Mechanical Characteristics of Hybrid Fiber Reinforced Concrete

Workability

The workability of Conventional concrete (HFRC 0) and Hybrid Fiber Reinforced Concrete (HFRC 1 – 5) was carried out as per the code IS: 456-2000 and Slump value of all mixes are furnished in Table 8.

Table 8. Slump values of Concrete mixes

S. No	**Mix Identification**	**Slump values (cm)**
1	HFRC 0	28
2	HFRC 1	28
3	HFRC 2	29
4	HFRC 3	29
5	HFRC 4	30
6	HFRC 5	30

Compressive Strength

The compressive strength of concrete was determined for Conventional and HFRC specimens. The compressive strength tests were carried out at the age of 7 and 28 days and it is shown in Fig. 3.

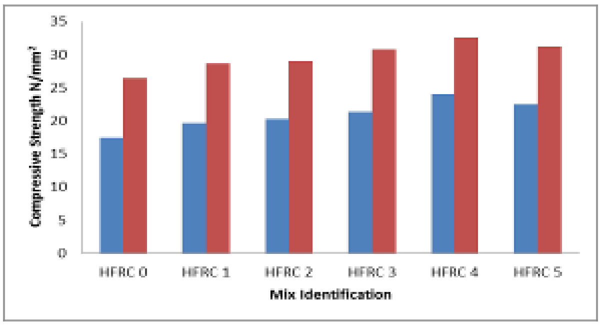

Fig.3.Compressive strength of Conventional and HFRC at the age of 7 and 28days

The maximum compressive strength was obtained in HFRC 4 mix with addition of 0.75% of Steel Fiber and 0.25% of PVA fiber due to optimum dispersion of fiber content at 7 days and 28 days. It is to be noted that the compressive strength of hybrid fiber reinforced concrete was increased up to the addition of 0.75% of Steel and 0.25% of PVA fiber in concrete.

Split Tensile Strength

The Split Tensile strength of Conventional and Hybrid Fiber Concrete mix at the age of 7 and 28 days are shown in Fig.4.

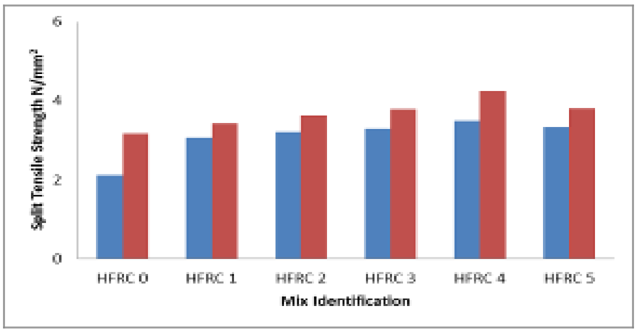

Fig.4. Split Tensile strength of Conventional and HFRC at the age of 7 and 28days

The test result shows that the split tensile strength of the concrete is higher in HFRC 4 Cylinder specimens. It represents 0.75% of Steel fibre and 0.25% of PVA fibre gives better result compare to conventional concrete.

Flexural Strength

The Flexural strength value for Conventional and HFRC specimens is shown in Fig.5. The test was carried out at the age of 28 days. The maximum flexural strength was obtained in the mix HFRC 4 with a value of 6.41MPa.

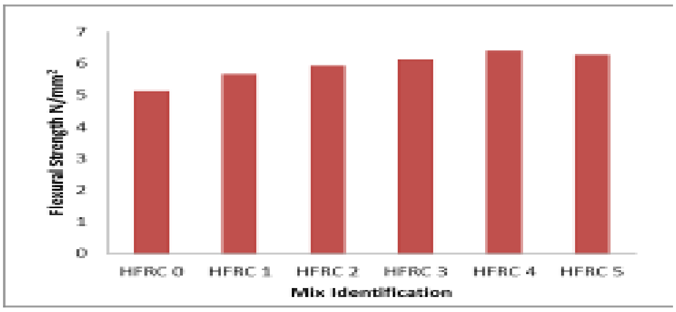

Fig.5. Flexural strength of Conventional and HFRC at the age of 28days

TEST RESULTS AND DISCUSSION OF STRUCTURAL BEHAVIOR OF BEAM7.1 Load carrying capacity and First crack load

All the beam specimens were tested till collapse. The first crack load and the corresponding deflection, the ultimate load and the corresponding deflection were measured for the entire beam (HFRC 0 – HFRC 5). The first crack load for conventional reinforced concrete HFRC 0 is 29.34 kN and the first crack load increases up to 59.8 kN for optimum dosage mix HFRC 4. The ultimate load carrying capacity of HFRC 4 is 1.36 times higher than plain reinforced concrete mix HFRC 0. The crack development is low for HFRC 4 when compared to HFRC 0 due to the presence of optimum dosage of hybrid fiber. The comparison of First crack load and Ultimate Load Carrying Capacity of the beam specimens are shown in Fig.6.

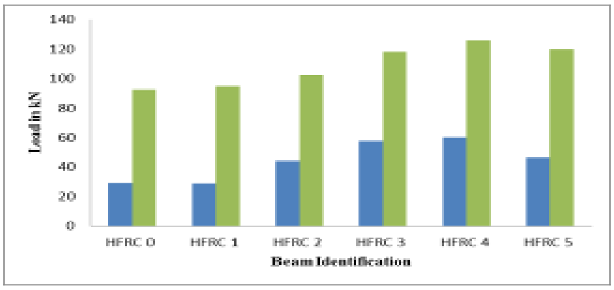

Fig.6. First crack and Ultimate load for Beam specimen

Load deflection behavior

The load deflection behaviour of all the specimens is shown in Fig.7. From the load deflection curve it is known that the HFRC 0 specimen indicate a sudden (brittle) failure whereas HFRC 4 specimen indicate a more ductile behavior. By comparing the entire specimen HFRC 4 that is 0.75% steel fiber and 0.25% PVA fiber carries more loads and withstands more deflection due to the presence of fiber having high modulus.

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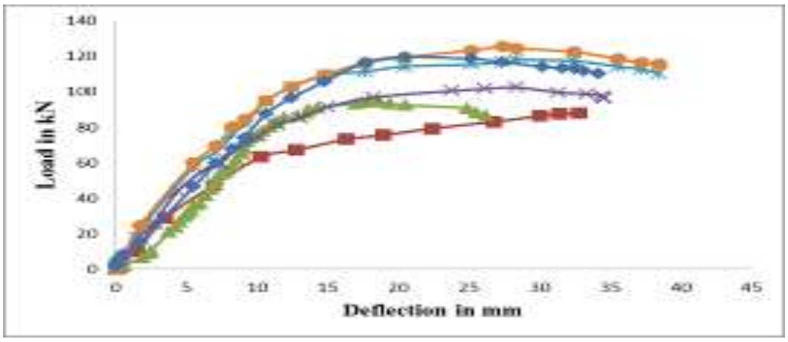

Fig.7. Load Deflection Curve for Conventional and HFRC Beam Specimens

Ductility behavior

The conventional concrete beam (HFRC 0) has a ductility value of 4.31. The ductility of HFRC 4 beam was measured and it increases about 1.37 times of HFRC 0 due to presence of Hybrid fibers. The comparison of ductility of beam specimens from HFRC 0 to HFRC 5 is shown in Fig.8.

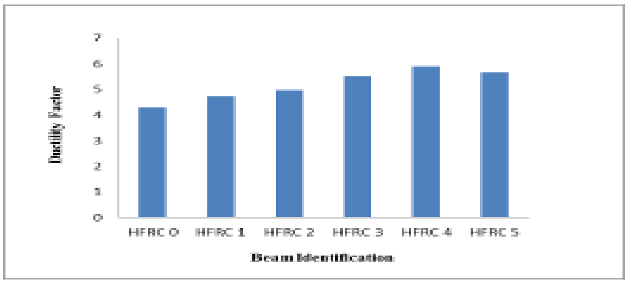

Fig. 8. Ductility comparison of Conventional and HFRC Beam specimens

Stiffness

The stiffness of the entire beam specimens are shown in Fig.9. The stiffness value of HFRC 4 has been increased by 1.63 times of HFRC 0.

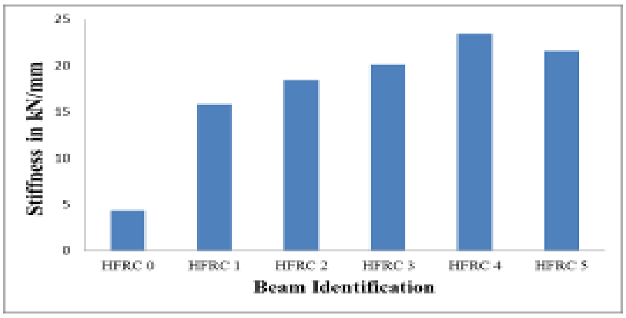

Fig.9. Stiffness comparison of Conventional and HFRC Beam specimens

Total Energy Absorption

Whenever a structure is subjected to loading some energy is absorbed by the specimen. In this investigation the area under the load-deflection curve gives the amount of energy absorbed by the specimen during loading. The total energy absorption for HFRC 4 increases up to 4.72 times when compared to conventional concrete. The total energy absorption of the beam specimens HFRC 0 to HFRC 5 are shown in Fig.10.

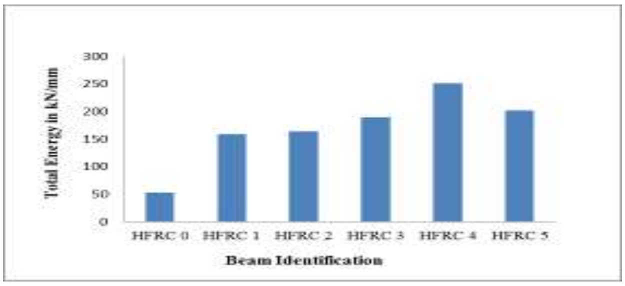

Fig. 10. Total Energy absorption of Conventional and HFRC Beam specimen

7.6 Energy Index

Energy Index is the ratio of total energy absorbed by the specimen up to Ultimate loading to that of the energy absorbed by the specimen during first crack. The Energy indexes for beam identification HFRC 0 to HFRC 5 are shown in Fig.11. From the test results it was found that HFRC 4 increases 3.45 times respectively compared to the Conventional concrete. HFRC 4 beam shows a maximum energy index value of 24.97 when compared to all other beams.

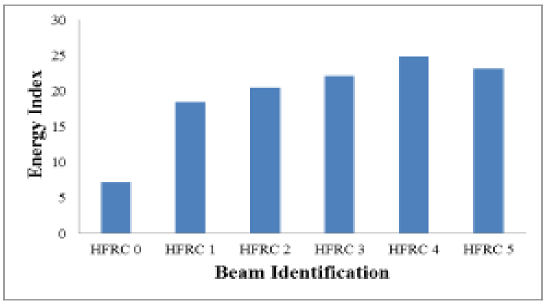

Fig.11. Energy Index of Conventional and HFRC Beam Specimen

8. CONCLUSION

Based on the experimental results of this research work it is found the hybridization of fiber proves to be better when compared to conventional reinforced concrete. From the mechanical performance it is found that the addition of 0.75% Steel fiber and 0.25% PVA fiber as optimum percentage of fiber addition in hybrid fiber reinforced concrete. There was 12% increase in compressive strength for HFRC 4 specimen when compared to HFRC 0 specimen. Hybridization also increased split tensile strength and flexural strength by 13% and 12% respectively. The first crack initiation load of (HFRC 4) specimen was 2 times more than conventional concrete (HFRC 0) and Ultimate Load carrying capacity increases about 13% compared to HFRC 0 specimen. The ductility of beam specimen (HFRC 4) was increased about 1.37 times than that of the conventional beam specimen (HFRC 0) due to presence of Hybrid Fiber in concrete. The stiffness value of the specimen (HFRC 4) also increases 1.63 times compared to conventional concrete. From the test result it is found that the improved mechanical properties of HFRC would result in reduction of short and long term cracking. The load carrying capacity of beam specimen with hybrid fiber strengthening is found to be more when compared to plain reinforced concrete. The ductility, stiffness, total energy absorption and energy index characteristics are higher for hybrid fiber reinforced concrete compared to conventional concrete, so that it is preferable to be used in area where structural failure is more.

References

1. Chunxiang Qian,Piet Stroeven, ‘Fracture properties of concrete reinforced with steel-polypropylene hybrid fibers’,Cement & concrete composites,pp.343-351,2000.
2. Eethar Thanon Dawood, Mahyuddin Ramli, ‘Contribution of Hybrid Fibers on the hybrid fobers on the properties of high strength concrete having high workability’,Procedia Engineering,pp.814-820,2011.
3. Eethar Thanon Dawood, Mahyuddin Ramli ‘High Strength charasteristics of cement mortar reinforced with hybrid fibers’, Construction and Building Materials,pp.2240-2247,2010.
4. Eethar Thanon Dawood, Mahyuddin Ramli, ‘Mechanical Properties of high strength flowing concrete with hybrid fibers’,Construction and Building Materials,pp.193-200,2011.
5. Mustafa Sahmaran, L Ozgur Yaman ‘Hybrid fiber reinforced self-compating concrete with a high-volume coarse fly ash’ ,Construction and Bilding Matrials.,pp.150-156,2005.
6. Palanisamy.T, Dineskumar.G, ‘Performance Evalution and investigation on mechanical properties of polyester fiber reinforced concrete’,Journal of structural engineering,vol.40,No.4,pp.420-425,2013
7. Palanisamy.T, Dineskumar.G, ‘Performance Evalution and structural behavior of basalt fiber reinforced concrete’, International Journal of Earth Sciences and Engineering, vol.07, No.2, pp.744-749,2014.
8. Patodi.S.C, Kulkarni.C.V ‘Performance Evaluation Of Hybrid Fiber Reinforced Concrete Matrix’, International Journal of Engineering Research and Applications.,Vol.2, pp.1856-1863, 2012.
9. Perumal.P, Thanukumari.B ‘Seismic performance of hybrid fibre reinforced Beam - Column joint’ International Journal Of Civil and Structural Engineering, Volume 1, No 4, pp. 749-763,2010.
10. Rajarajeshwari B Vibhuti, Radhakrishna, Aravind N ‘Mechanical Properties of Hybrid Fiber Reinforced Concrete for Pavements’, International Journal of Research in Engineering and Technology., pp 244 – 247,2013.