

Flexural Behaviour of Hybrid Fiber Reinforced Concrete Beams Strengthened by Glass FRP Laminate

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ABSTRACT: Concrete is one of the most resourceful and environmental friendly building material but since the brittle nature of concrete was found to be performing unsatisfactorily. This could manifest itself by poor performance under service loading, in the form of excessive deflections and cracking, this paper researches on special hybrid fiber combination of steel and polypropylene fiber in beams wrapped with Fiber Reinforced Polymer sheets. The flexural strength is one of the basic and important mechanical properties of concrete. Concrete is not usually expected to resist the direct tension because of its low flexure strength and brittle nature. The advantage of using FRP include light weight, ease of installation, minimal labor costs and site constraints, high strength to weight and durability. This paper presents the results of an experimental investigation carried out to evaluate the flexural strength and behavior of hybrid fiber reinforced concrete beam strengthened by glass FRP Laminate with the control beams. In general, it is concluded that Hybrid fiber reinforced concrete beam strengthened by Glass FRP laminate exhibited better performance than the conventional RC beam in all aspects.

KEYWORDS: FRP, flexure, durability, brittle, deflection, hybrid fibers.

I. INTRODUCTION

Concrete is generally characterized by quasi- brittle failure and is widely used construction material, This characteristic limits the usage of this material and can be recovered by addition of small amount of randomly distributed fibers such as glass, steel, synthetic and natural, which has low growth resistance, high shrinkage cracking, low durability etc. Fiber reinforced concrete is a concrete containing fibrous material which increases its structural integrity. The hybrid combination of metallic and nonmetallic fibers can produce potential pros in improving concrete properties as well as reducing the cost of concrete production. FRP composite materials have been successfully used in the construction and can be applied to strengthen the beams, columns and slabs of the buildings and bridges. FRP materials possess great promise for the future construction and in rehabilitation of existing structure. FRP technique results in increasing moment of inertia and behaves with more stiffness after wrapping.

II LITERATURE REVIEW

Beams were strengthened with chopped strand mat and woven roving glass fiber GFRP strengthened HFRC beams resulted in higher load carrying capacity and all strengthened beams failed in flexure mode only and the results obtained through ANSYS modeling for the specimen varied from 6 to 12.5% for yield deflection. (Raghunath et al, 2008)¹. The first crack load capacity of the beam with SFRC and HFRC were greater than that of RC beam without fiber and the deformation of RC beams improved with addition of fibers. The hybrid fiber system performed better than mono fiber system in load deflection behavior. The ductility performance of beam with SFRC and HFRC beam were improved. The brittle behavior as in plain RC beam was not observed in the FRC beams (Thiruganam et al, 2013)². The mechanical properties of hybrid fiber as 2 % volume fraction which inhibits the inclusion of steel fibers, synthetic fibers

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and palm fibers reduce flow-ability of the HSC whereas the partial replacement of steel fibers by palm fibers have less effect on flow ability of HSFC. The hybridization of steel fibers with palm fibers and barchip fibers enhances the static modulus of elasticity (Either thanon dawood etal, 2012)³. The effect of the fly ash content with steel and polypropylene fibers on the properties of fly ash concrete indicates increase in percentage of fly ash content, the compressive strength, split tensile strength and flexural strength of concrete decreases but this decrease is compensated by the use of fibers in concrete. Steel fibers give better results than polypropylene fibers. Observing the failure pattern of specimen, it is observed that the addition of steel fibers increases the ductility of flyash concrete. (Sharma et al, 2012)⁴. The effect of addition of mono fibers and hybrid fibers on the mechanical properties of concrete mixture results shows that hybrid fibers improve the compressive strength as compared to that of single fibers. Whereas, hybridization improves split tensile strength and flexural strength instantly. The improved mechanical properties of HFRC would result in reduction of warping stresses, short and long term cracking (Vibuti et al.)⁵. Hybrid Fiber Reinforced Concrete in Exterior Beam-Column Joint under Cyclic loading shows the results of fibers when used in a hybrid form could result in superior composite performance compared to their individual fiber-reinforced concretes. It was found that the addition of fibers bridges the cracking effects and delayed the formation of first crack. The ultimate load carrying capacity increases by 38% for hybrid when compared to steel fiber. (Muthupriya et al, 2014)⁶

III. EXPERIMENTAL PROGRAM

A. Material Properties

Cement

Ordinary Portland cement of 53 grade was used for casting conforming to IS 1489 (part 1): 1991. Specific gravity of cement is 3.15 and specific surface of cement is 277.8m²/kg.

Fine Aggregate

Clean and dry river sand locally available was used which was passing through IS 4.75mm sieve. Specific gravity of fine aggregate is 2.60, Water absorption is 1.21% and belongs to zone 1

Coarse aggregate

Coarse aggregate passing through 12.5 mm sieve as per IS 383-1970 was used. Specific gravity of coarse aggregate (12mm) is 2.70 and (20mm) is 2.75, Water absorption of (12mm) is 0.5% and (20mm) is 0.33%. The sieve analysis of coarse aggregate is single size aggregate for both sizes.

Water

Clean portable water was used for the entire project from casting to curing of specimens

Super plasticizer

Super plasticizer RHEOBUILD was added with a dosage of 0.7% to the weight of the binder content and dosage was adjusted with increase in

Steel Fibers

Hooked end fibers having 0.75 mm diameter, 60mm length with an aspect ratio of 80 was used.

Polypropylene Fibers

Fibrillated polypropylene fibers of size 12mm cut length were used.

B. Mix Proportion

M30 grade concrete mix was designed as per IS 10262:2009. The mix proportion calculated was 1:2.19:3.18 .No fibers were added in control specimens, whereas steel and polypropylene fibers were added to the concrete at a volume fraction of 0.5%.

C. Preliminary Studies

In the preliminary studies, standard size cubes of (150 x 150 x 150 mm), cylinder (70 mm diameter and 150 mm height) were tested. It is concluded that the compressive strength for steel 0.8% & polypropylene 0.2% at 7 and 28 days is higher than the control mix, split tensile strength at 7 and 28 days for steel 0.8% & polypropylene 0.2% is higher than the control specimens.

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D. Preparation of test specimens with Glass FRP

A total of five beams of size 100mm x 200mm x 1200mm were casted. One without hybrid fibers and other with hybrid fibers i.e. (steel + polypropylene). All the beams were reinforced with two numbers of 12 mm diameter rods at tension face (bottom) and two numbers of 10mm diameter at the top as hanger bars and 6mm stirrups spaced at 150mm center as shear reinforcement. Pan mixer of 40 litercapacity was adopted for casting the specimens. After 24 hours the beam mould was removed and beams are stored in water for curing for a period of 28 days. After 28 days of curing the beam was taken from water and dried for about 4 hours. The soffit of the beams was cleaned and GFRP Laminated was bonded using polyester adhesive. Then the beams were cured for seven days to permit the adhesive to gain strength, and after seven days the beams were white washed and prepared for testing.

E. Testing Of Beams

The beam specimens were placed in the universal testing machine of capacity 600kN and all the beams were tested under two-point loading. The beam is placed in one roller and one hinged supports, resting on iron blocks placed on wing table of the testing machine, the load is from the fixed cross head of the machine as two point load. Deflectometer were fixed at the midspan to measure the deflections. The beam was gradually loaded by increasing the load at each cycle. The beam was loaded till failure and first crack and ultimate load stage were noted.

IV. RESULTS AND DISCUSSION

Load Carrying Capacity

The first crack load and ultimate load carrying capacities of the beam was noted and shown in table 2 given below. It shows that the maximum load carrying capacity of the beam of percentage varying of 80% steel and 20% polypropylene were found to be higher than the control specimen and other varying percentage. It was clearly seen that adding the higher percentage of steel fibers and lower percentage of polypropylene will enhance the concrete strength and also acts as a crack resistance in order to delay the formation of cracks. The tabulation is shown below of table (1)

Table (1) Load Carrying Capacities of Beams

S.No	Type of beam	Load at first crack (kN)	Ultimate load (kN)
1	Plain RCC	34.50	137
2	Steel 0.5%-PP 0.5%	43.10	145
3	Steel 0.6%-PP 0.4%	46.15	147
4	Steel 0.7%-PP 0.3%	49.15	156.6
5	Steel 0.8%-PP 0.2%	59.75	158

Load deflection characteristics

The beam specimens were tested under two-point loading , as the load increased beam started to deflect and flexural cracks developed along the span of the beams, The deflection is noted and observed to be greater than the earlier cycle.. All the beams failed in same fusion. By plotting a graph between loads along x-axis, deflection along y-axis we can calculate ultimate load and flexural strength.

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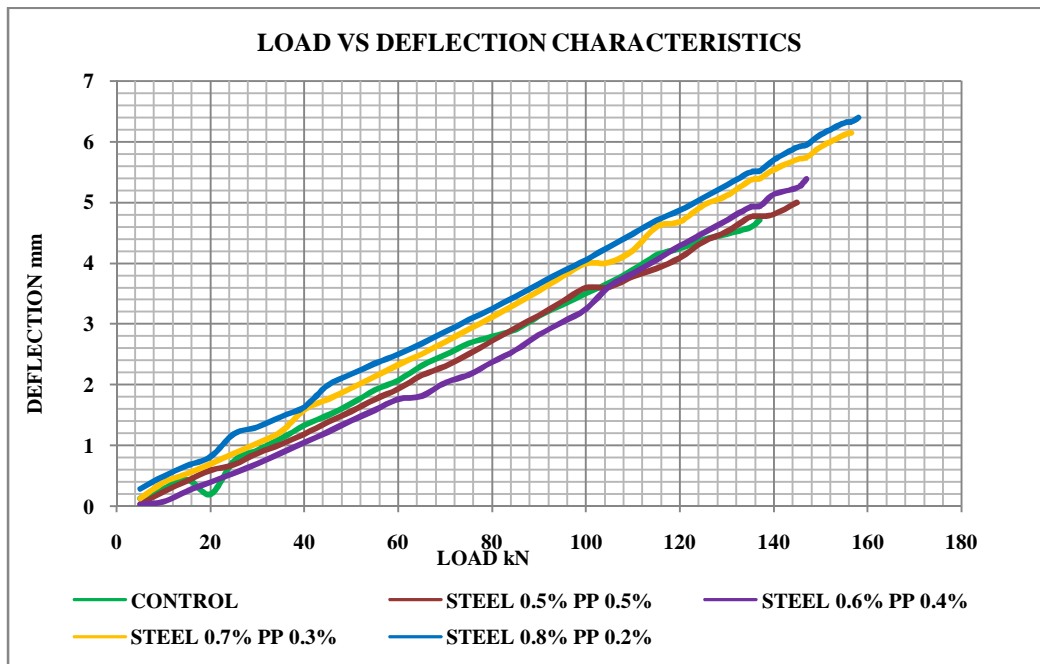


Figure (1) Load- Deflection Characteristics

The maximum observed deflection in the control specimen was 4.72mm. The maximum deflection of Hybrid Fiber Reinforced Concrete with the percentage varying in the range of 0.8% steel and polypropylene 0.2% was observed to be 6.4mm which is higher than the other varying percentages.

Table (2) Experimental Results of Beams

S.no	Specimen	First crack load (kN)	Midspan deflection (mm)	Ultimate load (kN)	Flexural strength (N/mm ²)
1	Control	34.50	4.722	137	41.1
2	Steel 0.5% - PP 0.5%	43.10	4.995	145	43.5
3	Steel 0.6% - PP 0.4%	46.15	5.385	147	44.1
4	Steel 0.7% - PP 0.3%	49.15	6.142	156.6	46.95
5	Steel 0.8% - PP 0.2%	59.75	6.4	158	47.4

At 0.8% of steel and 0.2% of polypropylene fiber, the strength is more than the other varying percentage. The micro cracks that normally form in concrete are arrested by fiber. The maximum ultimate load obtained from S0.8P0.2 is 158kN, the maximum deflection obtained from the percentage of S0.8P0.2 of 6.4 mm, the flexural strength of S0.8P0.2 is higher than the other varying percentages, all the beams failed by flexure and achieved greater strength than the conventional specimen

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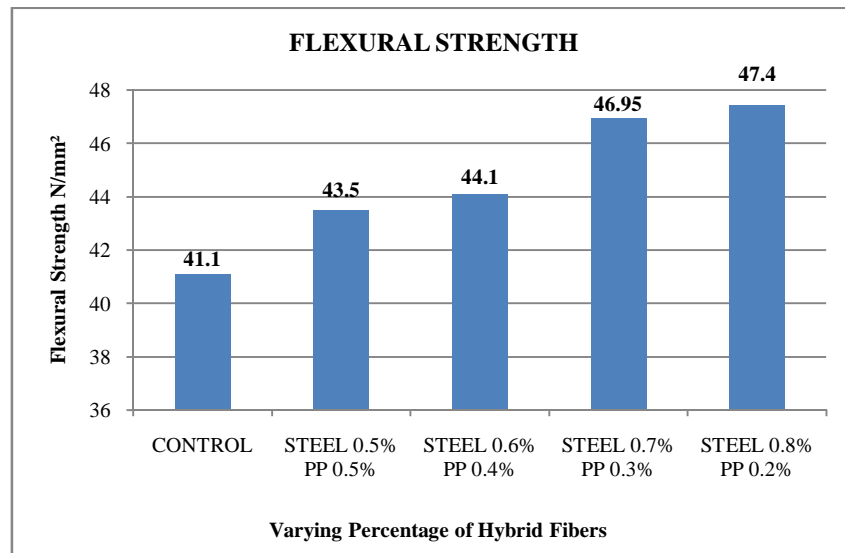


Figure (2) Comparison of Flexural Strength of Beams.

Behaviour and Mode of Failure

The Figure (3) showing the formation of shear cracks at the end supports of the beam which is due to propagation of flexural cracks. Shear cracks are formed usually near the edge of the support conditions and the control beam is failed due to flexural-shear failure. The control beam is without fibers and without glass fibre reinforced polymer laminate.



Figure (3) Closer View of Plain RC Beam without Fiber

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Figure (4) Closer View of HFRC Strengthened Beam

The Figure (4) showing the formation of flexural cracks at the mid-span of the beams and later on it extended till the shear end of the supports. The control specimen failed under the formation of shear cracks at the supports. HFRC beams are strengthened by glass fibre reinforced polymer laminate of single layer.

The flexural cracks initiated in the pure bending zone as expected. As the load increased existing cracks propagated and new cracks developed along the span. The flexural cracks gave way to inclined cracks due to the effect of shear force as shown in figure (5).



Figure (5) Closer View of Shear Crack at Supports in Strengthened HFRC beam

The failure pattern of all the beam specimens was found to be similar which failed in flexure mode whereas the control specimen failed due to flexure-shear pattern. The number of cracks is more and closely spaced to respective control beam due to addition of Hybrid Fibers and GFRP laminated at the soffit of the beam.

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Figure (6) Closer view of Flexural cracks in Strengthened HFRC beam

V. CONCLUSION

- The maximum compressive strength reaches in the HFC is S0.8P0.2, (i.e) 80% steel fibers and 20% polypropylene
- The split tensile strength of fiber percentage with S0.8P0.2 (i.e) 80% steel fibers and 20% polypropylene fibers shows slight increase in strength. Improved tensile strength can be achieved by increasing the percentage of steel fibers.
- Increasing the percentage of steel fiber in hybrid combination reduces slump value, to maintain the constant slump we have to increase the super plasticizers dose in concrete.
- The First crack load capacity of the beam 0.8% steel and 0.2% polypropylene fibers is 42.25 % greater than that of the unstrengthened RC beam without Hybrid Fibers.
- The ultimate load carrying capacity of GFRP strengthened HFRC beams of 0.8 % of steel and 0.2 % of polypropylene fibers exhibit an increase of 13.29 % than that of control specimen.
- The flexural strength of 0.8 % steel and 0.2 % polypropylene fibers is 13.29% greater than that of control specimen.
- Use of FRP laminate improves load carrying capacity; delays crack formation and energy absorption capability of beams reinforced with FRP laminates.
- The mode of failure in HFRC beam was more ductile in nature when compared with the control beam. All the beams strengthened with GFRP laminate experienced flexural failure. None of the beams exhibit premature failure of laminate. The failure pattern of all the beam specimens was found to be similar, and the failure zone is also similar in case of all the test specimens.

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