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Behaviour of Hybrid Fiber Reinforced Concrete Beam Strengthened Externally By GFRP 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 nonmetallicfibers 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

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 (Thirugnanam et al, 2013)¹. 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)². The specimens incorporated steel andpolypropylene fibres in the mix proportions of 00-00%, 0-100%, 25-75%, 50-50%, 75-25% and 100-00% byvolume at a total volume fraction of 1.0%. Compressive strength of concrete increases with the increasing percentage of fiber. Significant increase in flexural and shear strengths of FRC, in all the mix proportions, as fibre content increased from 0% to 1.0%. (Sangitav et al, 2010)³. Beams were strengthened with chopped strand mat and woven roving glass fiber GFRP strengthened HFRC beams resulted in higher load carrying



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capacity and all strengthened beams failed in flexure mode only and the results obtained (Raghunath et al, 2008)⁴.Investigation on the Flexural behavior of R.C.C. beam wrapped with GFRP sheet to study strength, ductility and damage level of R.C.C. under reinforced beam. Effective procedure of wrapping enhances the strength considerably including the change of failure mode as well as change the location of failure plane (Pudale Yojana et al, 2015)⁵.Strength Behaviour of Fibre Reinforced Polymer Strengthened Beam- The study parameters included first crack load, yield load, ultimate load, first crack deflection, yield deflection, ultimate deflection, crack width, deflection ductility, energy ductility, deflection ductility ratios and energy ductility ratios of the test beams and was concluded that the effect of bonding GFRP laminate influences the behavior of beams by increasing deflection by 56.4% and load carrying by more than 71.40% (Pannirselvam et al, 2009)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.

GFRP Laminate

Glass fiber reinforced polymer laminates of thickness 3mm were used.

B. Mix Proportion

M30 grade concrete mix was designed as per IS 10262:2009. The mix proportion calculated was 1:2.02:3.38 .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 $(150 \times 150 \times 150 \text{ mm})$, cylinder (150 mm diameter and 300 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.

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 10 mm diameter rods at tension



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face (bottom) and two numbers of 8mm diameter at the top as hanger bars and 8mm stirrups spaced at 150mm center as shear reinforcement. Pan mixer of 40 liter capacity 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.



Figure(1) Longitudinal section of beam.

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. EXPERIMENTAL RESULTS

Compressive strength of HFC Cube

Cube mould of $150 \text{mm} \times 150 \text{ mm} \times 150 \text{mm} \text{ were casted for finding the compressive strength of HFRC. In which hybrid fibre with different hybridization ratio were added in concrete and compressive strength of cube was calculated by using compression testing machine. Compressive strength of cubes at 7th and 28th day was obtained and tabulated.$

S.No	Specimen	Compressive Strength at 7 th day	Compressive Strength at 28 th day	
		(N/mm ²)	(N/mm²)	
1	Control	21.28	33.42	
2	0.5% Steel-0.5% PPF	23.05	35.88	
3	0.6% Steel-0.4%PPF	25.08	37.62	
4	0.7% Steel-0.3%PPF	26.42	39.64	
5	0.8% Steel-0.2% PPF	27.95	42.41	

Table(1) Compressive strength of HFC cube at 7th& 28th day.

Split Tensile strength of HFC Cylinder

Cylindrical mould of 150 mm diameter and 300mm long are used for casting the specimen for split tensile strength and the results were tabulated below.



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S.No	Specimen	Split Tensile Strength at 7 th day	Split Tensile Strength at 28 th day	
		(kPa)	(kpa)	
1	Control	2.04	3.36	
2	0.5% Steel-0.5% PPF	2.28	3.70	
3	0.6% Steel-0.4% PPF	2.46	3.89	
4	0.7% Steel-0.3% PPF	2.78	4.34	
5	0.8% Steel-0.2% PPF	3.19	4.95	

Table(2) Split Tensile strength of HFC cylinder at 7th& 28th day.

FlexuralStrength of beams

The first crack load and ultimate load carrying capacities of the beam was noted and shown in table 3 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.

S.No	Type of Beam	First Crack Load	Midspan	Ultimate Load	Flexural Strength
		(k N)	Deflection (mm)	(k N)	(N/mm ²)
1	Plain RCC	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	6.124	156.6	46.95
5	Steel 0.8%-PP 0.2%	59.75	6.4	158	47.4

Table(3) Experimental results on Beams.

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.



Figure(2) Comparison of flexural strength.



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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.



LOAD VS 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.

Behaviour and Mode of failure

The Figure (4) 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(4) Closer view of plain RC beam without Fiber.

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Figure(5) Closer view of HFRC Strengthened Beam.

The Figure (5) showing the formation of flexural cracks at the mid-span of the beams and later on it extended till theshear end of the supports. The control specimen failed under the formation of shear cracks at the supports. HFRCbeamsare 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 andnew cracks developed along the span. The flexural cracks gave way to inclined cracks due to the effect of shear force asshown in figure (6).



Figure(6) Closer view of shear crack at supports in HFRC Strengthened 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.

V. CONCLUSION

- The maximum compressive strength and split tensile strength reaches in the HFC S0.8P0.2, (i.e) 80% steel fibers and 20% polypropylene fibers.
- ★ The compressive strength of HFC (0.8S0.2P) are 21.20% greater than that of the control specimen.



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- The compressive strength of HFC (0.8S0.2P) are 32.12% greater than that of the control specimen. Improved tensile strength can be achieved by increasing the percentage of steel fibers.
- Slump cone & compaction factor valves diminishes with Addition of filaments, It is so in light of the fact that as the strands are included the draining will be decreased and the blend will get to be unforgiving. From this we can reason that as the rate of fiber substance is expanded, the workability will be diminished.
- ✤ As the rate increment in filaments the compaction variable qualities diminishes. From this we can infer that the workability of the blend diminishes as the fiber content in the solid increments.
- 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 & ultimate load capacity of the beam 0.8% steel and 0.2% polypropylene fibers 42.25 % and 13.29% greater than that of the unstrengthen RC beam without Hybrid fibers respectively.
- ★ 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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