FLEXURAL BEHAVIOUR OF HYFRC BEAM REINFORCED WITH GFRP REBAR

Tamilanban G[1], Subashchandran B [2]
[1, 2]Assistant Professors, Department of civil Engineering,
TKR College of Engineering, Hyderabad, Telangana State , India.

ABSTRACT

This paper presents the experimental study on the flexural behaviour of HYFRC beams reinforced with glass fiber reinforced polymer (GFRP) rebar and compared with normal steel reinforcement beams. Three beams reinforced with GFRP rebar and three beams of conventional concrete steel reinforced with totally six beams were casted and tested under two points loading. The companion specimens were casted along with beam and tested for concrete properties. From testing, load carrying capacity, load-deflection characteristics, crack pattern, crack width, concrete strains across cross section and failure mode were noted stiffness, ductility and energy dissipation capacity were also calculated. The average ultimate load carrying capacity of GFRP rebar and normal steel reinforcement beam is 125.8KN and 97.5KN respectively. The maximum deflection noted at their ultimate load in the GFRP rebar and normal steel reinforcement beam is 27.3 mm and 16.3 mm respectively. It was also observed that after load removal, deflected GFRP beam regain its original position and crack width also reduced. In steel beam, steel rebar were yielded, after load removal, no deflection regain and crack width reduction were found.

Keywords: GFRP, Hybrid fibre, flexural testing, stiffness, ductility and energy dissipation capacity.

1. INTRODUCTION

Concrete is a versatile construction material used worldwide. Concrete technologists are continuously carrying out the research to improve the performance of concrete to meet the functional, strength and durability requirement. Concrete has the drawback of being weak in tension, porous and susceptible for environmental attack. The difficulties of plain concrete were overcome is satisfied, by adding fibre to improve density for better performance. The necessity for new non corrosive material because of corrosion problems associated with steel.

In the present work was to investigate load-deformation characteristics, load carrying capacity, failure mode, stress-strain characteristics across cross section and flexural performance of HYFRC beam reinforced with GFRP rebar and it was compared the flexural behaviour of conventional concrete beam reinforced with rebar.

Annadurai et al[2001] have experimentally studied the flexural behaviour of high strength concrete grade of M60 using hooked ends steel fibres, polyolefin straight fibres in various volume fractions. They were focused on evaluating the ductility and energy absorption capacity. The test results showed that hybrid fibre of volume fraction 2% with steel 80%-polyolefin 20% combination specimen improves the flexural performance appreciably compared with that of control specimen and steel fibre reinforced high strength concrete specimen.

Priyanka Dilip et al[2008] they have described the study on the mechanical performance of Hybrid fibre reinforced concrete (HFRC). The addition of small closely spaced and uniformly dispersed fibres to concrete would act as crack arrester and would substantially improve its static and dynamic properties.Here Steel fibre and polyolefin fibre are used as Hybrid fibre. They are used in four different proportions as 0%, 0.5%, 1%, 1.5% and 2% in this study. They concluded that fibre content in concrete increases, the strength also increases up to a certain extent. Mix containing 1% Hybrid fiber showed maximum performance. Yamini roja, et al [2015] have investigated static behavior of concrete beams reinforced with GFRP beams were carried out to study the flexural behavior under static monotonic loading. Due to the low modulus of elasticity of GFRP bars, the crack initiation load was found to be early in beams with GFRP reinforcement when compared to beams with conventional TMT reinforcement. They concluded that average values of crack initiation loads for beams with GFRP and TMT reinforcement were 11.4 kN and 20.1 kN respectively. Similarly, the average values of ultimate load carrying capacity for beams with GFRP and TMT reinforcement were 82.9 kN and 97.6 kN respectively

2. EXPERIMENTAL PROGRAM

2.1MATERIALS USED

2.1.1 CEMENT:

Ordinary Portland cement conforms to IS 10262-2009 penna cement 53 grade produced from single source was used. The specific gravity of the cement is 3.15.

2.1.2 FINE AGGREGATE:

Locally available river sand was used as fine aggregate which passes through 4.75mm as per IS 383-1978. The specific gravity of the fine aggregate is 2.67. Zone 3was used. The fineness modulus of aggregate was 2.8.

2.1.3 COARSE AGGREGATE:

Locally available coarse aggregate brought from hosur 20mm size aggregate was used. The specific gravity of the coarse aggregate is 2.74. The fineness modulus of aggregate was 3.58.

2.1.4 WATER:

Potable water which is available in laboratory is used for casting and curing of specimen as per IS 456-2000. W/C .45 was in mix.

2.1.5 STEEL FIBER:

Steel fibre with hooked end was used. The properties of steel fibre with their specification are mentioned below table 1.

2.1.6 GLASS FIBER:

CEMFIL anti crack AR glass fibre (alkali resistant) was used. The properties of glass fibre with the specification are mentioned below table 2.

TABLE 1: Properties of Steel Fibre

PROPERTIES	SPECIFICATIONS
Type of steel fibre	Crimped
Material	Low carbon drawn flat wire
Length	50mm
Diameter of fibre	0.5mm
Aspect ratio	50
Percentage	1 % (volume of cement)

TABLE 2: Properties of Glass Fibre

PROPERTIES	SPECIFICATIONS
Type of glass fibre	Alkali resistant (AR)
Length	12 mm
Diameter of fibre	14 micron
Aspect ratio	857.1
Percentage	1 % (volume of cement)

In the present investigation replacement of steel reinforcement as glass fiber reinforced polymer. GFRP bars posse’s mechanical properties different from steel bars, including high tensile strength combined with low elastic modulus and elastic brittle stress-strain relationship.

2.1.8 CONCRETE MIX PROPOTION:

Mix proportion of M35 grade concrete was designed as per IS 10262-2009 and IS 456-2000. The proportion and w/c ratio for M35 is 1:1.77:2.84, 0.45.

2.2 REINFORCEMENT DETAILS:

The experimental investigation includes casting and testing of six beams of dimension (1800 mm length, 150 mm width and 250 mm depth). Beams were simply supported at their ends with the effective span of 1500 mm. A view of longitudinal section and cross section of a typical beam specimen is shown fig.1. Three beams were casted with HYFRC with GFRP rebar as longitudinal reinforcement. 3 beams were casted with conventional concrete with steel rebar in HYFRC beam steel and glass fibres were used. GFRP 2nos of rebar of 10 mm diameter was used as reinforcement at top and bottom for shear 6mm stirrups 6mm diameter 2 legged vertical were used at 150mm c/c. Steel 2nos of 10mm diameter main bar and mm stirrups were used for 3 beams. TMT 10 mm diameter main bar and 6 mm stirrups were used for three beams. Bottom and top side concrete clear cover of 20 mm was maintained for all beams. Reinforcement details shown below Fig 1.

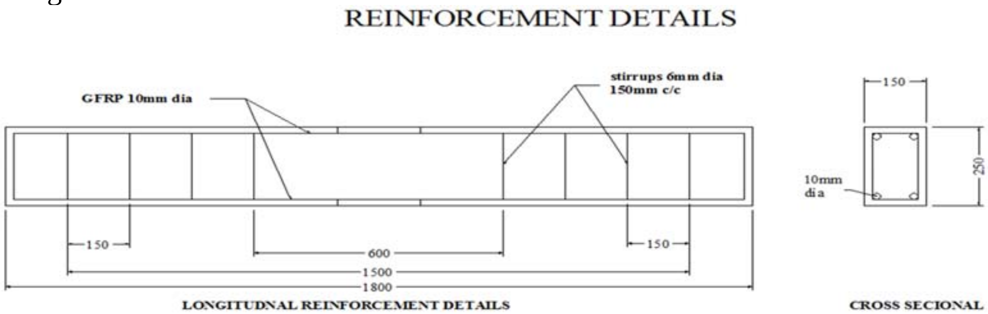

Figure 1 Reinforcement Details

2.3CASTING AND CURING

Compressive strength of HYFRC companion specimen was casted as follows. 3nos of 150X150X150 mm cube, 150x300 mm cylinders and 3nos of prism were casted 100x100x500 mm prism specimen were casted and tested for compressive, split tensile and flexural strength of concrete. Similarly for conventional concrete above side specimens and tested. Specimens are shown below Fig 2 a,b,c.

a) moulding b) casting c) curing

Figure 2 moulding, Casting and Curing of Specimens

3. TEST PROGRAMME

The test setup involves a two point loading system by using a spread beam and two rollers. Totally 3 LVDTs one 100mm, two 50mm LVDTs were used to measure deflection placed at the mid span of beam along the tension side. Two 50mm LVTDs were used under two points loading to measure deflection. A 50mm dial cage was placed near beam end to measure the rotation. Pellets were placed as shown in Fig 3 at mid span across cross section of beam to measure concrete strain. The point loads acts at a distance of 200mm from the mid span along the compression side of the beam. Test setup shown in Fig 4.

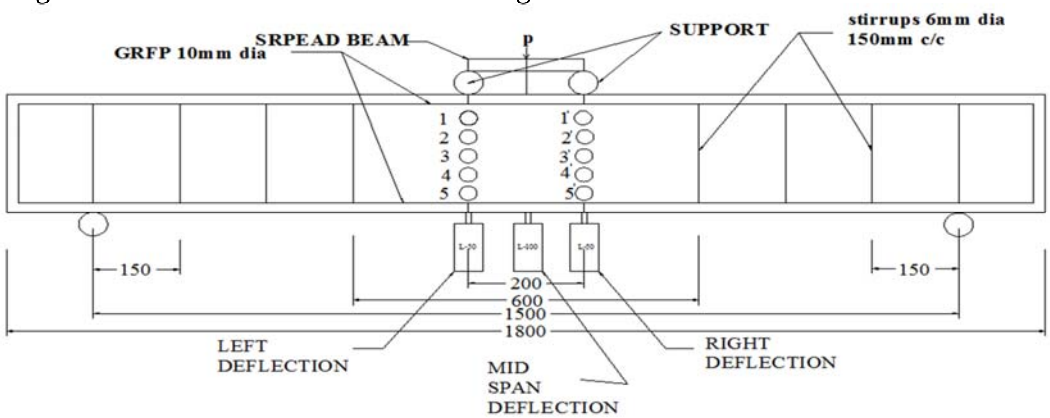

Figure 3 Placing of LVDTs

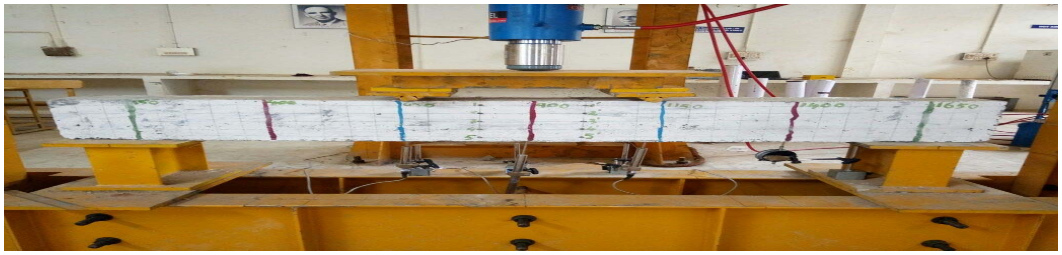

Figure 4 Test setup

4. RESULT AND DISCUSSION

4.1 CUBE TEST RESULT

Compressive strength is the maximum compressive stress that, under a gradually applied load, given solid material can sustain without fracture. Compressive strength is calculated by dividing the maximum load by the original cross section area of the specimen in compression test. Cube test result mentioned below in table 3.

TABLE 3: Test Results of Compressive Strength of Concrete

S.NO	SPECIMEN	WEIGHT (kg)	DIMENSION (mm)	INITIAL LOAD (kN)	FINAL LOAD (kN)	COMPRESSIVE STRENGTH (N/mm²)	AVG (N/mm²)
1.	HYFRC-1	7.870	150x150	898	944	41.95	40.66
2.	HYFRC-2	7.945	150x150	720	880	39.11	
3.	HYFRC-3	7.475	150x150	760	921	40.93	
4.	N-1	8.645	150X150	763	874	38.48	38.37
5.	N-2	8.415	150X150	516	824	38.07	
6.	N-3	8.515	150X150	652	839	38.57	

4.2 CYLINDER TEST RESULT

The tensile strength of concrete is not able to measure directly. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. Concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack. Cylinder test results are mentioned below in table 4.

TABLE 4: Test Result of Split Tensile Strength of Concrete

S.NO	SPECIMEN	WEIGHT (kg)	DIMENSION (mm)	FINAL LOAD (kN)	SPLIT TENSILE STRENGTH(N/mm²)	AVG (N/mm²)
1.	HYFRC-1	12.825	150x300	189	2.7	2.87
2.	HYFRC-2	13.030	150x300	194	2.9	
3.	HYFRC-3	13.345	150x300	202	3.01	
4.	N-1	13.175	150X300	187	2.7	2.63
5.	N-2	13.080	150X300	194	2.74	
6.	N-3	13.155	150X300	173	2.45	

4.2 PRISM TEST RESULT

Flexural strength also known as modulus of rupture, or bend strength, or transverse rupture is a material property, defined as the stress in a material just before it yields in a flexure test.

TABLE 5: Test Result of Flexural Strength of Concrete

S.NO	SPECIMEN	WEIGHT (kg)	DIMENSION(mm)	FINAL LOAD(kN)	FLXERUAL STRENGTH(N/mm²)
1.	HYFRC-1	13.125	100x100x500	14.5	12.83
2.	HYFRC-2	13.330	100x100x500	12	
3.	HYFRC-3	13.145	100x100x500	12	
4.	N-1	12.815	100X100X500	9.25	8.75

5.	N-2	13.200	100X100X500	10.5	
6.	N-3	12.7	100X100X500	6.5	

4.3 LOAD CARRYING CAPACITY

A beam is a structural element that primarily resists loads applied laterally to the beam's axis. Its mode of deflection is primarily by bending.

TABLE 6: Test Result of load carrying capacity

S.No	SPECIMEN	INITIAL CRACK LOAD(kN)	ULTIMATE LOAD(kN)
1.	HYFRC-1	40	160.3
2.	HYFRC-2	30	110.1
3.	HYFRC-3	35	107
4.	N-1	21	76.6
5.	N-2	20.6	120
6.	N-3	30	96

FOR SPECIMEN 1

TABLE 7: Various Deflection of HYFRC-1

S.NO	LOAD(kN)	DEFLECTION1	DEFLECTION2	DEFLECTION3
1.	0	0	0	0
2.	25	0.7	0.7	0.8
3.	38	3.7	3.9	3.9
4.	48	5.7	5.9	5.9
5.	60	7.6	8.1	7.8
6.	73	10.1	10.7	10.1
7.	83	11	11.5	11
8.	93	13.2	14.1	13.4
9.	103	15.1	16.1	15.4
10.	113	16.7	17.6	17.3
11.	122	17.6	18.7	18.2
12.	135	20.1	21.5	21
13.	143	21.5	22.6	22.3
14.	153	25.3	26.1	25.8
15.	160.3	28.9	29.7	29

Figure 7 Load Vs Middle Deflection Hyfrc - 1

LOAD CARRYING CAPACITY OF HYFRC BEAM REINFORCED WITH GFRP REBAR

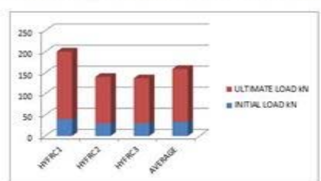

Figure 5 Load Carrying Capacity of Hyfrc Beam

FOR SPECIMEN 2

TABLE 8: Various Deflection of HYFRC-2

S.NO	LOAD (kN)	DEFLECTION1	DEFLECTION2	DEFLECTION3
1.	0	0	0	0
2.	10	0.1	0.1	0.1
3.	20	0.2	0.3	0.2
4.	30	0.8	0.8	0.8
5.	40	3.8	4.4	3.9
6.	50	6.7	7.1	6.2
7.	60	9.5	9.8	8.8
8.	70	11.4	11.7	10.2
9.	80	14	14.2	12.3
10.	90	16.2	16.3	14
11.	100	19.9	20.5	17.1
12.	110.3	24.1	25.3	20.7

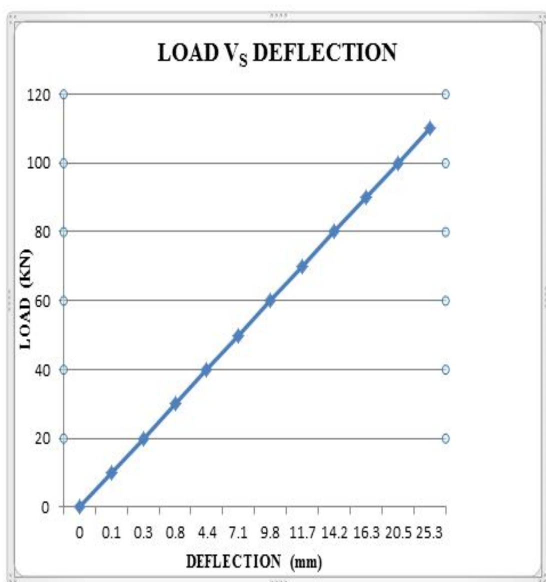

Figure 8 Load Vs Middle Deflection Hyfrc - 2

FOR SPECIMEN 3

TABLE 9: Various Deflection of HYFRC-3

S.NO	LOAD(kN)	DEFLECTION1 mm	DEFLECTION2 mm	DEFLECTION3 mm
1.	0	0	0	0
2.	10	0.2	0.1	0.2
3.	25	1.1	1.1	1.1
4.	35	5.9	6.3	5.9
5.	45	9	9.6	8.7
6.	60	9.1	10	9
7.	70	11.6	13	11.6
8.	85	14.4	16.2	14.4
9.	100	19	22	19
10.	107	24	27	24

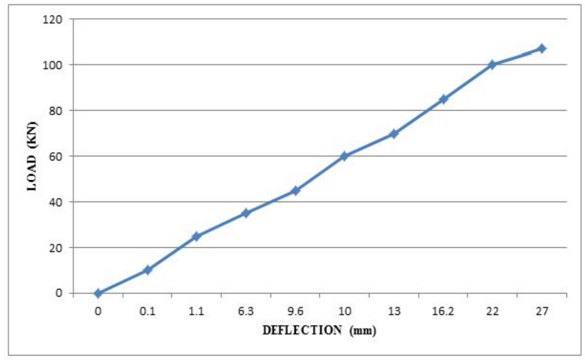

Figure 9 Load Vs Middle Deflection Hyfrc - 3

CONCRETE BEAM REINFORCED WITH STEEL REBAR

FOR SPECIMEN 1

TABLE 10: Various Deflection of NORMAL -1

S.NO	LOAD (kN)	DEFLECTION 1 (mm)	DEFLECTION 2 (mm)	DEFLECTION 3 (mm)
1.	0	0	0	0
2.	30.6	0	1.2	0.4
3.	40.6	0	1.3	0.4
4.	53.8	0.3	2.9	1.1
5.	57.2	0.5	3.4	1.4
6.	67	0.8	4.1	1.7
7.	76.6	2.8	8	3.6

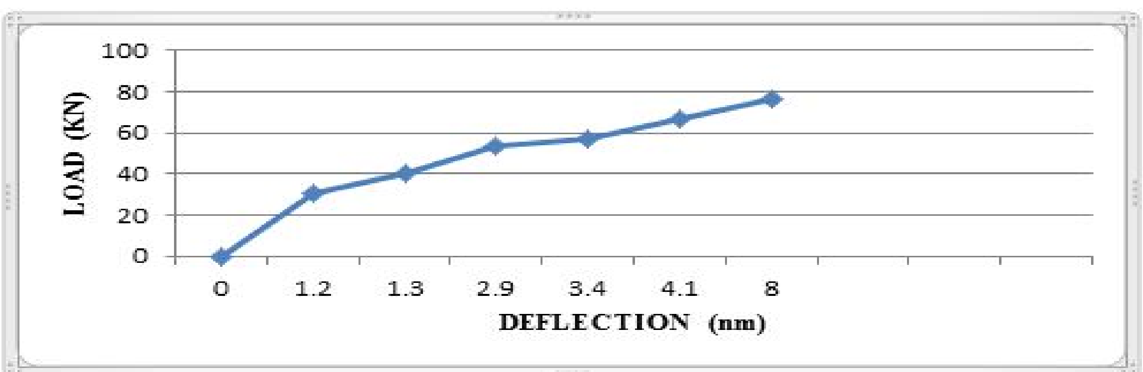

Figure 9 Load Vs Middle Deflection Normal - 1

FOR SPECIMEN 2

TABLE 11: Various Deflections of Normal -2

S.NO	LOAD (kN)	DEFLECTION 1 (mm)	DEFLECTION 2 (mm)	DEFLECTION 3 (mm)
1.	0	0	0	0
2.	20.6	0.9	0.9	0.8
3.	30.6	1.4	1.8	1.3
4.	44	2.3	2.8	2.3
5.	54	3.4	3.9	3.4
6.	64.5	3.7	4.4	3.8
7.	76	4.3	5.1	4.5
8.	86	5.3	6.3	5.8
9.	120	14.8	17.1	17.6

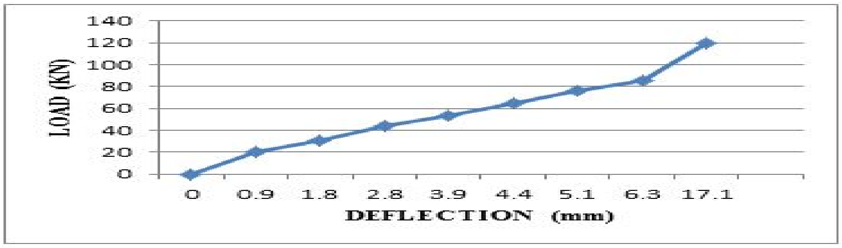

Figure 10 Load Vs Middle Deflection Normal - 2

FOR SPECIMEN 3

TABLE 12: Various Deflections of NORMAL -3

S.NO	LOAD (kN)	DEFLECTION 1 (mm)	DEFLECTION 2 (mm)	DEFLECTION 3 (mm)
1.	0	0	0	0
2.	21	0.3	1.0	1.3
3.	32	1.5	2	2.6
4.	42	2.2	3	3.4
5.	52	2.5	3	3.7
6.	63	3.4	4	4.8
7.	73	5.3	7	7
8.	96	22.1	24	23.9

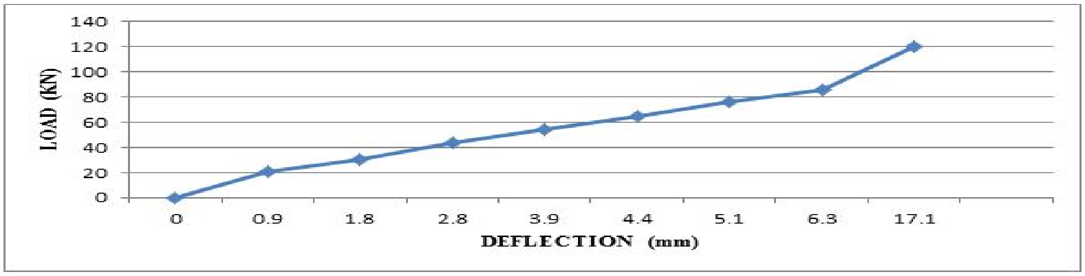

Figure 11 Load Vs Middle Deflection Normal - 3

4.5 STIFFNESS

Stiffness is the rigidity of an object – the extent to which it resists deformation in response to an applied force.

Stiffness is measured in force per unit length (N/mm), and is equivalent to the “force constant” in Hooke’S Law.

Stiffness $\mathbf{K} = \boldsymbol{P}/\Delta \boldsymbol{y}$

TABLE 12: Initial Stiffness and Final Stiffness

S.NO	SPECIMEN	INITIAL STIFFNESS (N/mm)	FINAL STIFFNESS (N/mm)	AVERAGE (N/mm)
1.	HYFRC-1	47.5	5.397	$4.569X10^3$
2.	HYFRC-2	37.5	4.35	
3.	HYFRC-3	5.55	3.96	
4.	N-1	23.53	9.575	$2.18X10^3$
5.	N-2	11.44	6.818	
6.	N-3	21	4	

4.6 DUCTILITY

Ductility is defined as the ability of a material to deform easily upon the application of tensile force, or as the ability of material to with stand plastic deformation without rupture.

As no yield point found, no ductility p-Δ relation is linear upto failure in HYFRC beams. HYSD

$$\text{Ductility} = \Delta/\Delta y$$

TABLE 13: Ductility Result

S.NO	SPECIMEN	DUCTILITY
1.	HYFRC-1	NO YIELD
2.	HYFRC-2	
3.	HYFRC-3	
4.	N-1	0.104
5.	N-2	0.146
6.	N-3	0.250

4.7 ENERGY DISSIPATION CAPACITY:

A reinforced concrete member dissipate energy by experincing in elastic behaviour during cyclic loading. The test result shown below in the table 14.

TABLE 14: Energy dissipation capacity result

S.NO	SPECIMEN	Energy dissipation capacity (N-mm)	AVERAGE (N-mm)
1.	HYFRC-1	0.254	0.201
2.	HYFRC-2	0.163	
3.	HYFRC-3	0.187	
4.	N-1	0.068	0.140
5.	N-2	0.134	
6.	N-3	0.226	

4.8 CRACK PATTERN:

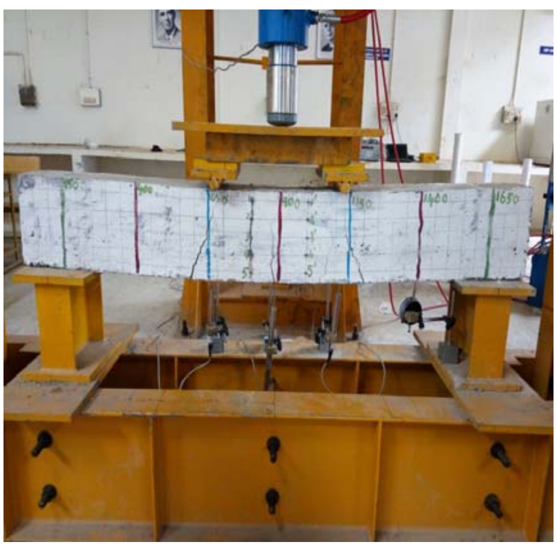

Figure 18 Ultimate Load Deflection Profile

Figure 19 After load removal beam regain its normal position

5. CONCLUSION

Based on the experimental investigation conducted on beams under two points loading. The following conclusions are drawn:

- The maximum compressive split tensile and flexural strength HYFRC beam greater than conventional concrete.
- The load carrying capacity of HYFRC beam was found to be 29% greater than the value of conventional concrete beam.
- The value of HYFRC beam for load Vs deflection is about 29.7mm greater than conventional concrete beam which is 16.36mm. GFRP does not under goes failure. Failure occurs in concrete
- The stiffness of HYFRC beam was found to be 1.09% greater than the value of conventional concrete beam.
- As no yield point found, no ductility p-Δ relation is linear upto failure in HYFRC beams. But conventional concrete beam which is 0.166.
- The value of HYFRC beam for energy dissipation capacity is about 43.57% greater than conventional concrete beam.
- Replacement of steel bar with GFRP bar beam has shown better result in flexural load carrying capacities.
- The addition of hybrid fibre at concrete reduces the crack under loading conditions. The brittleness of concrete can also be improved by the addition of steel and glass fibre. Since concrete weak in tension, the fibres are beneficial in axial-tension to increase tensile strength.
- The use of GFRP bars in beam has yielded not only greater flexural strength to the beam but also good shear capacities and bending moment.
- GFRP bar have weaker elasticity modulus, which generate more deflection for equal and span.
- The average value of crack initiation loads for beam with GFRP and TMT reinforcement were 35 KN and 20.06 KN respectively. The average value of ultimate load carrying capacity for beams with GFRP and TMT reinforcement were 125.8 KN and 97.5 KN respectively.

REFERENCE

1) Mr.Ranjith Kumar.R , Ms.Vennila.A," Experimental Investigation on Hybrid Fibre Reinforced Concrete", International Journal of Emerging Trends in Engineering and Development, Vol.2 (March 2013),PP(39-45).
2) Selina ruby G., Geethanjali C., Jaison varghese, P. Muthu priya," Influence of Hybrid Fiber on Reinforced Concrete", International Journal of Advanced Structures and Geotechnical Engineering, Vol. 03, Jan 2014,PP(40-43).
3) Kavita S Kene, Vikrant S Vairagade and Satish Sathawane, Bonfring , "Experimental Study on Behavior of Steel and Glass Fiber Reinforced Concrete Composites", International Journal of Industrial Engineering and Management Science, Vol. 2, No. 4, December 2012,PP(1-4).
4) P. Sangeetha, "Study On The Compression And Impact Strength Of Gfrc With Combination Of Admixtures", Journal of Engineering Research and Studies, , Vol.2 (JUNE 201),PP(36-40).
5) Wakchaure M. R., Rajebhosale S. H., Satpute M. B., Kandekar S. B, "Comparison Of Compressive Strength And Flexural Shear Strength For Hybrid Fibre Reinforced Concrete With The Controlled Concrete", International Journal of Engineering and Technical Research,Volume-02, September 2014,PP(172-175).
6) G. Suguna B.E, Mrs.S.Parthiban M.E, "Experimental and Investigation of Hybrid Fiber Reinforced Concrete" International Journal of Innovative Science, Engineering & Technology, Vol. 3, May 2016, PP(409-414).
7) R.H. Mohankar, M.D. Pidurkar, P.V Thakre, S.S. Pakhare, "Hybrid Fibre Reinforced Concrete," International Journal of Science, Engineering and Technology Research , Volume 5, January 2016,(1-4).
8) V. Madhu Kiran, Brijbhushan S, Dr.Prakash K B, "A Comparative Study On Mechanical Properties Of Hybrid Fiber Reinforced Concrete With Controlled Concrete", International Research Journal of Engineering and

Technology ,Vol: 02 ,Sep-2015,PP(402-407).

9) G B. Maranan, A C. Manalo, W Karunasena, B Benmokrane, D Lutze "Flexural behaviour of glass fibre reinforced polymer bars subjected to elevated temperature",23rd Australasian Conference on the Mechanics of Structures and Materials, vol. I, 9 Dec(20014), pp. 187-192
10) Austin Beau Connor "Experimental investigation on the shear characteristics of gfrp reinforcement systems embedded in concrete" Electronic Theses and Dissertations,(2014),pp-1 to 81.
11) Shahul Mohammed, S.Natarajan "Experimental study on flexural behaviour of rc beams strengthened with g.f.r.p" International Journal For Research In Emerging Science And Technology, volume-3, jun-2016 ,pp- 1 to 7.
12) Pappula Ravi Kumar,E.Balakoteswar Rao "Flexural behaviour of rc beam retrofitted with gfrp", International Journal & Magazine of Engineering, Technology, Management and Research A Peer Reviewed Open Access International Journal , Volume No: 2, September 2015
13) Ali S. Shanour, Ali S. Shanour, Maher A. Adam , Mohamed Said "Experimental investigation of concrete beams reinforced with gfrp bars" International Journal Of Civil Engineering And Technology, Volume 5, November (2014), Pp- 279 to 282.
14) Ramadass S & Job Thomas "Flexure-shear analysis of concrete beam reinforced with gfrp bar", The 5th International Conference on FRP Composites in Civil Engineering, September 2010,pp-1 to 5.
15) S. Marvel Dharma, S. Yamini Roja "Review on behaviour on glass fibre reinforced polymer RC members", International Conference on Explorations and Innovations in Engineering & Technology (2016), pp-21 to 23.
16) Shrikant M. Harl, "Review on the performance of glass fiber reinforced concrete", International Journal of Civil Engineering Research,Volume 5, (2014), pp. 281-284