Flexural Behaviour of HYFRC Beam Reinforced with GFRP Rebar

S.Kamala Kannan

Abstract— This paper offers the experimental have a take a look at at the flexural behaviour of HYFRC beams bolstered with glass fiber bolstered polymer (GFRP) rebar and in comparison with everyday metal reinforcement beams. Three beams reinforced with GFRP rebar and three beams of traditional concrete metal strengthened with absolutely six beams have been casted and tested under two points loading. The partner specimens were casted along with beam and tested for concrete homes. Steel and glass fibres are used toimprove the concrete assets. From checking out, load carrying capability, load-deflection traits, crack sample, crack width, concrete traces throughout move phase and failure mode have been mentioned stiffness, ductility and power dissipation potential had been additionally calculated. The average ultimate load wearing potential of GFRP rebar and normal steel reinforcement beam is one hundred twenty five.8KN and ninety seven.5KN respectively. The most deflection cited at their closing load inside the GFRP rebar and regular metal reinforcement beam is 27. Three mm and sixteen. 3 mm respectively. It changed into also found that after load elimination, deflected GFRP beam regain its authentic function and crack width also reduced. In metal beam, metallic rebar were yielded, after load elimination, no deflection regain and crack width reduction have been observed.

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

1. INTRODUCTION

Concrete is a versatile construction material used global. Concrete technologists are constantly carrying out the research to beautify the overall performance of concrete to satisfy the beneficial, energy and sturdiness requirement. Concrete has the downside of being weak in anxiety, porous and prone for environmental attack. The problems of simple concrete were overcome is happy, via including fibre to decorate density for better overall performance. The necessity for new non corrosive material because of corrosion problems associated with metal.

Glass fibre strengthened polymer (GFRP) bars and hybrid fibre had been applied in present studies to deal with the problem of corrosion related to metal. GFRP rebar are mild in weight and approximately one 1/three in evaluation to that metallic.

In the winning paintings was to investigate load-deformation tendencies, load wearing capacity, failure mode, stress-strain traits at some point of pass segment and flexural universal performance of HYFRC beam strengthened with GFRP rebar and it modified into compared the flexural behaviour of conventional concrete beam strengthened with rebar.

Annadurai et al[1]have experimentally studied the flexural behaviour of excessive energy concrete grade of M60 the use of hooked ends metallic fibres, polyolefin immediately fibres in numerous extent fractions. In this study durability indices were calculated through using the experimental load deflection. They had been centered on comparing the ductility and power absorption ability. The check consequences confirmed that hybrid fibre of quantity fraction 2% with metal eighty%-polyolefin 20% combination specimen improves the flexural performance notably compared with that of manipulate specimen and steel fibre bolstered immoderate strength concrete specimen. PriyankaDilip et al[2] they have got described the look at on the mechanical general performance of Hybrid fibre bolstered concrete (HFRC). The addition of small carefully spaced and uniformly dispersed fibres to concrete might act as crack arrester and may considerably enhance its static and dynamic residences. Here Steel fibre and polyolefin fibre are used as Hybrid fibre. They are used in 4 distinct proportions as 0%, 0.Five%, 1%, 1.Five% and a pair of% in this examine. They concluded that fibre content material in concrete increases, the energy additionally will increase as much as a sure quantity. Mix containing 1% Hybrid fiber confirmed most overall performance. Yaminiroja, et al [3]have investigatedstaticbehavior Of concrete beams bolstered with GFRP beams have been carried out to have a look at the flexural behavior underneath static monotonic loading. Due to the low modulus of elasticity of GFRP bars, the crack initiation load turned into determined to be early in beams with GFRP reinforcement even as in comparison to beams with traditional TMT reinforcement. They concluded that not unusual values of crack initiation loads for beams with GFRP and TMT reinforcement had been eleven. Four kN and 20.1 kN respectively. Similarly, the common values of closing load sporting capacity for beams with GFRP and TMT reinforcement have been 80 two.Nine kN and 97.6 kN respectively

2. EXPERIMENTAL PROGRAM

2.1 MATERIALS 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 sandwas 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.

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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:

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

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)

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 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)

2.1.7 GFRP REBAR:

In the existing studies substitute of metallic reinforcement as glass fiber bolstered polymer. GFRP bars posse's mechanical houses special from metal bars, inclusive of high tensile energy mixed with low elastic modulus and elastic brittle pressure-pressure relationship.

2.1.8 CONCRETEMIX PROPOTION:

In the present studies substitute of steel reinforcement as glass fiber strengthened polymer. GFRP bars posse's mechanical houses unique from metal bars, such as high tensile energy mixed with low elastic modulus and elastic brittle stress-strain relationship.

2.1.9 CONCRETEMIX PROPOTION:

Mix share of M35 grade concrete end up designed as in keeping with IS 10262-2009 and IS 456-2000. The proportion and w/c ratio for M35 is 1:1.Seventy seven:2.84, 0.45.

2.2 REINFORCEMENT DETAILS:

The experimental research includes casting and testing of six beams of dimension (1800 mm duration, 100 fifty mm width and 250 mm intensity). Beams had been absolutely supported at their ends with the effective span of 1500 mm. A view of longitudinal section and go segment of a wellknown beam specimen is confirmed fig.1.Three beams have been 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 six mm stirrups were used for 3 beams. Reinforcement details shown below Fig 1.

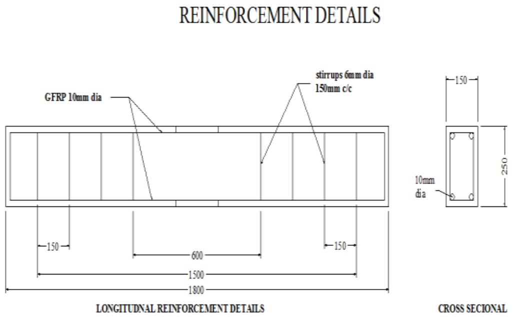
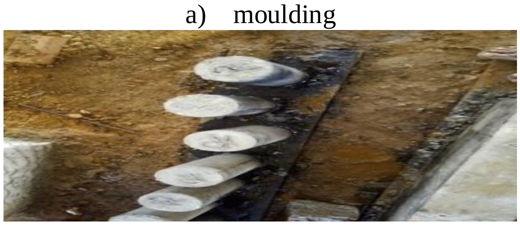


Figure1Reinforcement Details

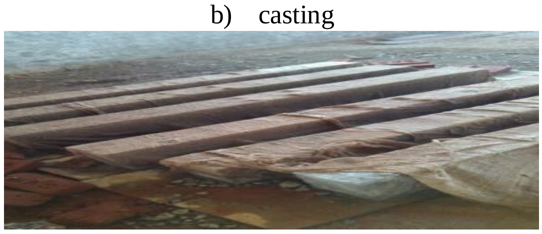
2.3CASTING AND CURING

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 2a,b,c.

a) moulding



b) casting



c) curing

Figure2moulding,Casting and Curing of Specimens

3. TESTPROGRAMME

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.

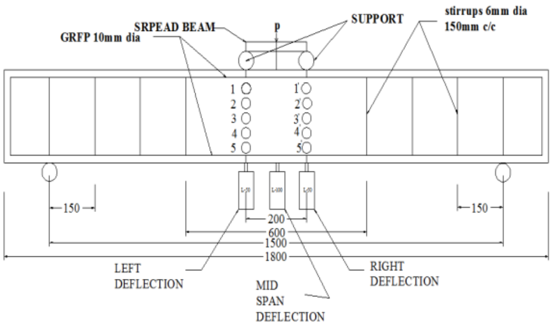


Figure 3 Placing of LVDTs

Figure 4Test setup

4. RESULT AND DISCUSSION

4.1 CUBE TEST RESULT

Compressive electricity Is the maximum compressive pressure that, beneath a regularly applied load, given strong cloth can preserve without fracture. Compressive electricity is calculated by dividing the maximum load through the authentic move section area of the specimen in compression take a look at. Cube check result referred to beneath 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 energy of concrete is not able to degree without delay. Splitting tensile power Test on concrete cylinder is a way to determine the tensile strength of concrete. Concrete develops cracks when subjected to tensile forces. Thus, it's miles vital to determine the tensile strength of concrete to determine the load at which the concrete individuals can also moreover crack. Cylinder test results are referred to below in desk 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	

4.3 PRISM TEST RESULT

Flexural energy additionally called modulus of rupture, or bend energy, or transverse rupture is a fabric belongings, defined as the pressure in a fabric simply before it yields in a flexure take a look at.

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	

4.4 LOAD CARRYING CAPACITY

A beam is a structural detail that typically resists loads carried out laterally to the beam's axis. Its mode of deflection is normally by way of way of 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

LOAD CARRYING CAPACITY OF HYFRC BEAM REINFORCED WITH GFRP REBAR

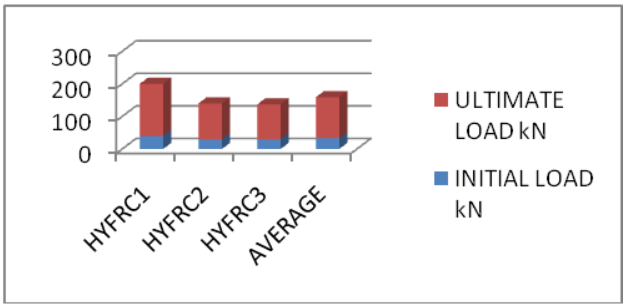


Figure 5 Load Carrying Capacity ofHyfrc Beam

LOAD CARRYING CAPACITYOF CONVENTIONAL BEAM REINFORCED WITH STEEL BAR

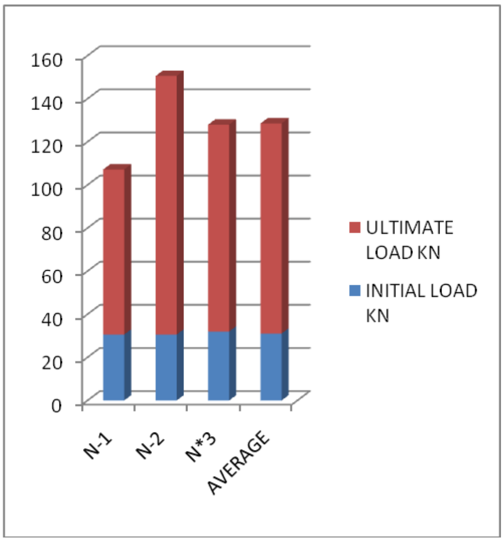


Figure 6Load Carrying Capacity of Normal Beam

4.5 LOADVERSUS DEFLECTIONCHARACTERISTICS

In this 3 LVDTs were placed to measure the left deflection, middle deflection and right deflection (such as deflection 1, deflection 2 and deflection 3).

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

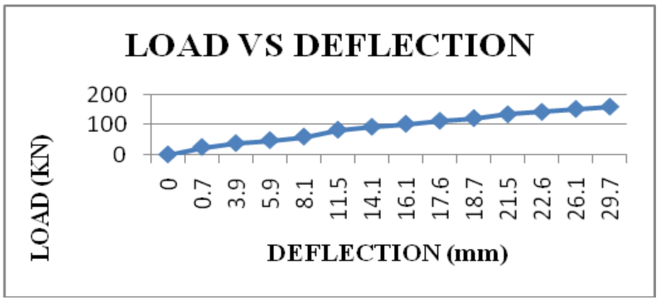


Figure 7 Load Vs Middle Deflection Hyfrc - 1

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

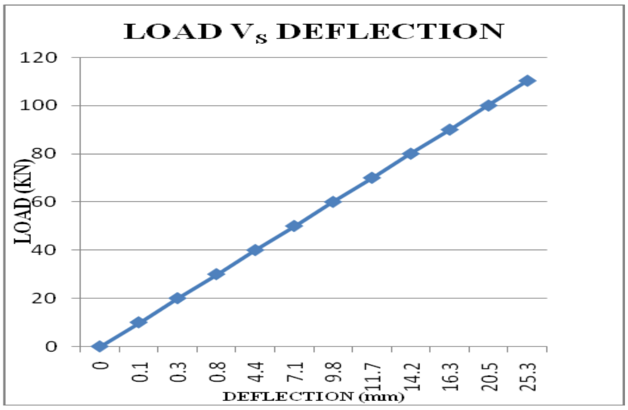


Figure 8 LoadVs Middle Deflection Hyfrc - 2

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

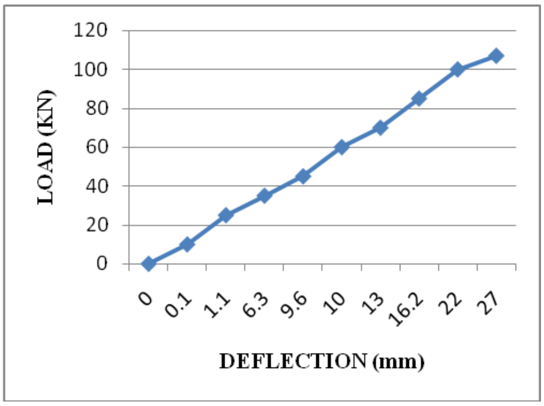


Figure 9 Load Vs Middle Deflection Hyfrc - 3

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

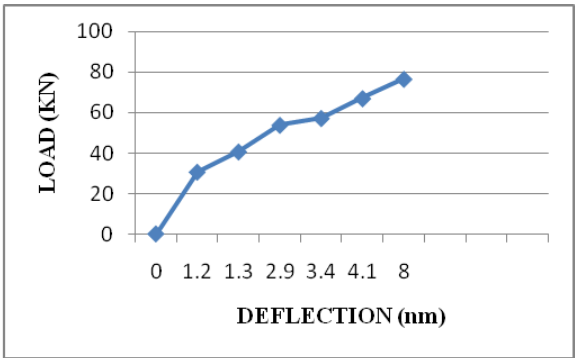


Figure 9 Load Vs Middle Deflection Normal - 1

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

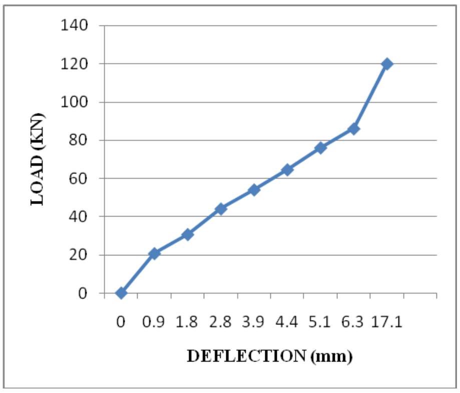


Figure 10 Load Vs Middle Deflection Normal - 2

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

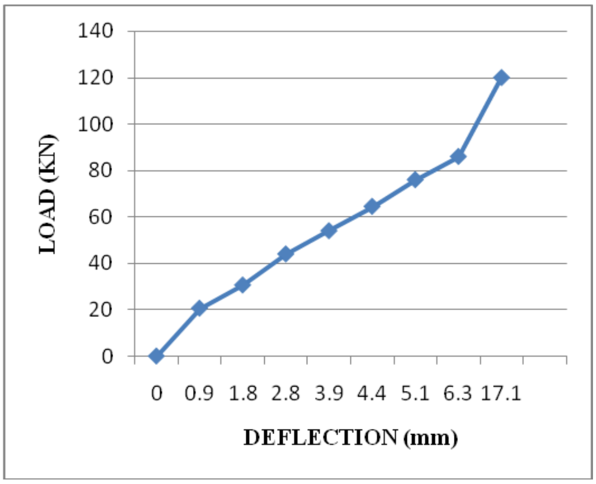


Figure 11 Load Vs Middle Deflection Normal - 3

4.6 MOMENTVsROTATIONCHARACTERISTICS:

It is the best second the beam can experience proper before or right as it starts offevolved to fail on paper. It is a mathematically determined range. It does not bear in mind, element of safety, nor inferior high-quality of cloth, human errors at some stage in fabrication or any other real world scenario. It's just a mathematical calculation of the beams capability in a perfect world.

The theoretical, applied bending moment that will cause failure in a reinforced concrete member through yield in the tensile reinforcing steel or crushing of concrete

FOR BEAM SPECIMEN 1:

TABLE 13:Ultimate Moment forHYFRC-1

S.NO	LOAD (kN)	M (kN-m)	ROTATION
1.	0	0	0
2.	25	16.25	0.05
3.	38	24.70	0.10
4.	48	31.20	0.15
5.	60	39.00	0.15
6.	73	47.45	0.20
7.	83	53.95	0.20
8.	93	60.45	0.25
9.	103	66.95	0.25
10.	113	73.45	0.25
11.	122	79.30	0.30
12.	135	87.75	0.35
13.	143	92.95	0.35
14.	153	99.45	0.45
15.	160.3	104.19	0.45

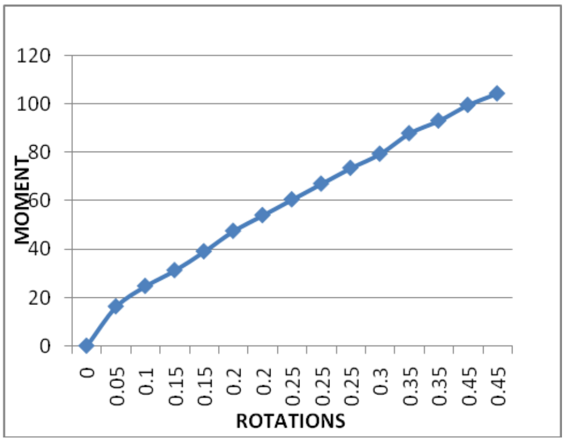


Figure 12 Moment Vs Rotation Hyfrc - 1

FOR BEAM SPECIMEN 2:

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TABLE 14:Ultimate Moment forHYFRC-2

S.NO	LOAD (kN)	M (kN-m)	ROTATION
1.	0	0	0
2.	10	6.5	0.0005
3.	20	13	0.0008
4.	30	19.5	0.050
5.	40	26	0.100
6.	50	32.5	0.100
7.	60	39	0.150
8.	70	45.5	0.150
9.	80	52	0.200
10.	90	58.5	0.200
11.	100	65	0.200
12.	110.3	71.69	0.250

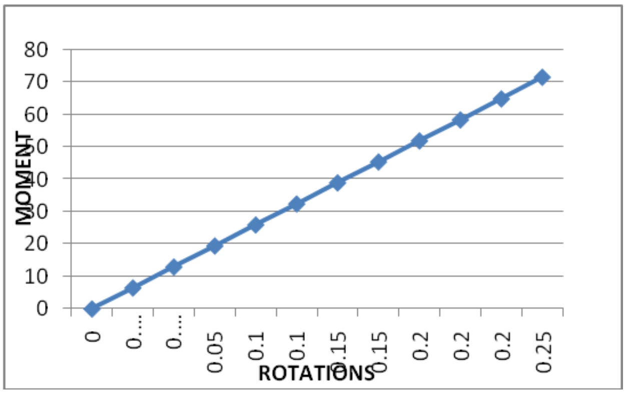

Figure 13 Moment Vs Rotation Hyfrc - 2

FOR SPECIMEN 3:

TABLE 15:Ultimate Moment forHYFRC-3

S.NO	LOAD (kN)	M (kN-m)	ROTATION
1.	0	0	0
2.	10	6.5	0.0002
3.	25	16.25	0.0504
4.	35	22.75	0.150
5.	45	29.25	0.150
6.	60	39	0.200
7.	70	45.5	0.200
8.	85	55.25	0.200
9.	100	65	0.250
10.	107	69.55	0.250

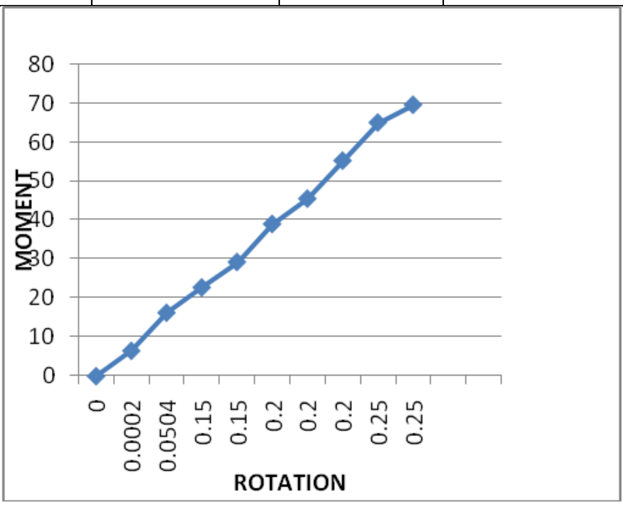

Figure 14 Moment Vs Rotation Hyfrc - 3

CONCRETE BEAM REINFORCED WITH STEEL REBAR

FOR SPECIMEN 1

TABLE 16:Ultimate Moments forNORMAL-1

S.NO	LOAD (kN)	M (kN-m)	ROTATION
1.	0	0	0
2.	30.6	19.89	0.05
3.	40.6	26.39	0.05
4.	53.8	34.97	0.10
5.	57.2	37.18	0.10
6.	67	43.55	0.10
7.	76.6	49.79	0.15

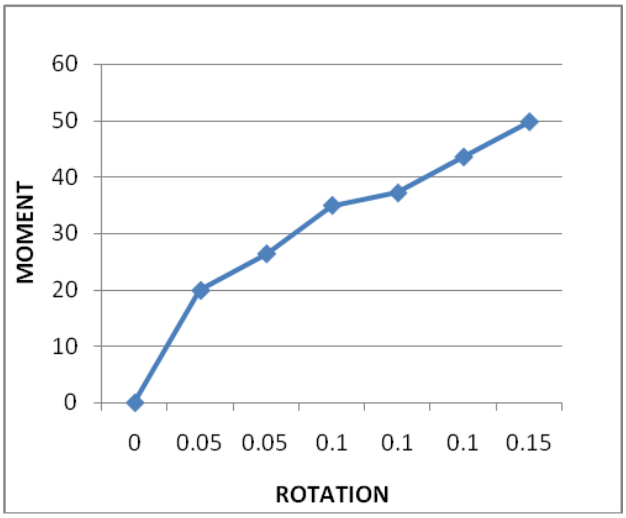

Figure 15 Moment Vs Rotation Normal - 1

FOR SPECIMEN 2:

TABLE 17:Ultimate Moments forNORMAL-2

S.NO	LOAD (kN)	M (kN-m)	ROTATION
1.	0	0	0
2.	20.6	13.39	0
3.	30.6	19.89	0
4.	44	28.60	0.05
5.	54	35.10	0.05
6.	64.5	41.92	0.05
7.	76	49.40	0.05
8.	86	55.90	0.10
9.	120	78.0	0.20

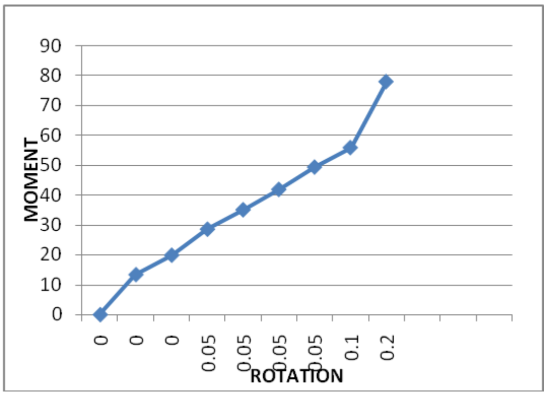

Figure 16 Moment Vs Rotation Normal – 2

FOR SPECIMEN 3:

TABLE 18:Ultimate Moments forNORMAL-3

S.NO	LOAD (kN)	M (kN-m)	ROTATION
1.	0	0	0
2.	21	13.65	0.05
3.	32	20.80	0.05
4.	42	27.30	0.05
5.	52	33.80	0.05
6.	63	40.95	0.05
7.	73	47.45	0.10
8.	96	62.40	0.10

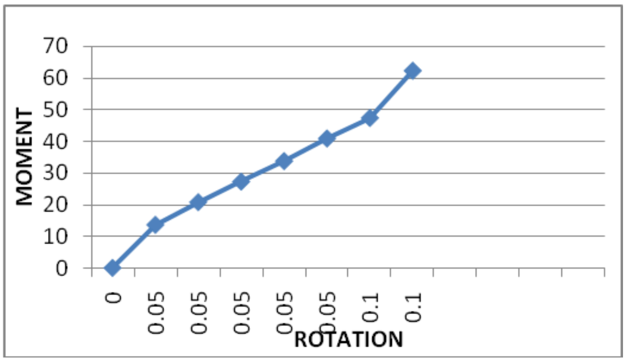

Figure 17 Moment Vs Rotation Normal – 3

4.6 STIFFNESS

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

Stiffness is measured in pressure in keeping with unit period (N/mm), and is equivalent to the "force steady" in Hooke'S Law.

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

TABLE 19: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	

4.7 DUCTILITY

Ductility isdefined As the potential of a material to deform without difficulty upon the application of tensile force, or because the potential of material to with stand plastic deformation with out 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 20: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

4.8 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 21.

TABLE 21: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	

4.9 CRACK PATTERN:

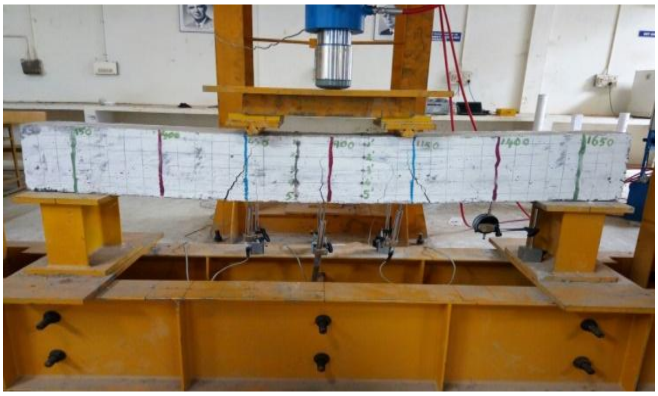

Figure18Ultimate Load Deflection Profile

Figure19 After load removal beam regain its normal position

5. CONCLUSION

Based at the experimental research conducted on beams under factors loading. The following conclusions are drawn:

- The most compressive cut up tensile and flexural strength HYFRC beam greater than conventional concrete.
- The load sporting capability of HYFRC beam turned into found to be 29% extra than the price of conventional concrete beam.
- The price of HYFRC beam for load Vs deflection is ready 29.7mmgreater than conventional concrete beam which is 16.36mm. GFRP does now not under is going failure. Failure happens in concrete
- The stiffness of HYFRC beam turned into found to be 1.09% extra than the price of conventional concrete beam.
- As no yield point observed, no ductility p- relation is linear upto failure in HYFRC beams. But conventional concrete beam that's zero.166.
- The price of HYFRC beam for power dissipation capacityis about 43.57 greater than traditional concrete beam.
- Replacement of metallic bar with GFRP bar beam has proven better result in flexural load wearing capacities.
- The addition of hybrid fibre at concrete reduces the crack beneath loading conditions. The brittleness of concrete additionally may be advanced with the useful resource of the addition of metallic and glass fibre. Since concrete vulnerable in anxiety, the fibres are beneficial in axial-tension to boom tensile strength.
- The use of GFRP bars in beam has yielded not most effective more flexural electricity to the beam however also properly shear capacities and bending second.
- GFRP bar have weaker elasticity modulus, which generate extra deflection for equal and span.
- The common value of crack initiation masses for beam with GFRP and TMT reinforcement have been 35 KN and 20.06 KN respectively. The average fee of closing load sporting capacity for beams with GFRP and TMT reinforcement have been 100 twenty 5.8 KN and 90 seven.Five KN respectively.

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