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Strengthening of Beams Using Glass Fiber Reinforced Polymer (GFRP) Laminate

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ABSTRACT

Several infrastructures around the globe are getting damaged day by day due to improper maintenance, environmental conditions, improper design, poor construction, etc. Through research, they have found many techniquesand development to strengthen the construction in order to provide good strength and reliability. One such development in composite strengthening system is Fiber-Reinforced polymer (FRP) application. Fiber-reinforced polymer technique is one of the effective methods used in strengthening rehabilitating infrastructure which are very weak in strength. While comparing with other reinforcing methods, FRP method is much more economical as well as provides long time durability and strength. Through this study, we are examining the flexural and shear characteristics of reinforced concrete (RC) beams by using Glass fiber polymer laminate. The beams which are to be examined is coated and strengthened with 1.5 mm Epoxy Bonded Glass Fiber Reinforced Polymer (GFRP) and tested. The beam is tested until it fails by using a symmetric two-point load system. 10 beams of size 155 mm × 155 mm × 1010mm were constructer, out of which 7 beams were coated with GFRP laminate made out of different combination and 3 beams were control beams. The beams were tested and the deflection of each beam were recorded and compared with the deflections od control beams respectively.

Keywords: polymer, beams, laminate, composite, infrastructure

INRTODUCTION

Many weak structures like bridges, buildings, off shore structures and gliders. The reasons for damage might be due to poor construction, lack of maintenance, due to environmental conditions, poor designing, etc. therefore such structures might lack their strength and they will not be able to bare the load.So, such structures should be strengthened and rehabilitated or else they should be replaced, otherwise they may cause harmful disaster. So, strengthening the structure can help them to hold the load as well as gives them a very good durability. For strengthening the structures, the dimensions of the structures are enlarged, reinforced and some additional supports may be used. So, by strengthening, the structures will be able to resist the forces and tension caused while applying load. Some of the common methods used like Glass Fiber Reinforced polymer (GFRP) are Carbon Fiber Reinforced Polymer (CFRP) and Armid Fiber Reinforced Polymer (AFRP) techniques. Studies were conducted in order to determine the structural characteristics of beams reinforced with FRP.

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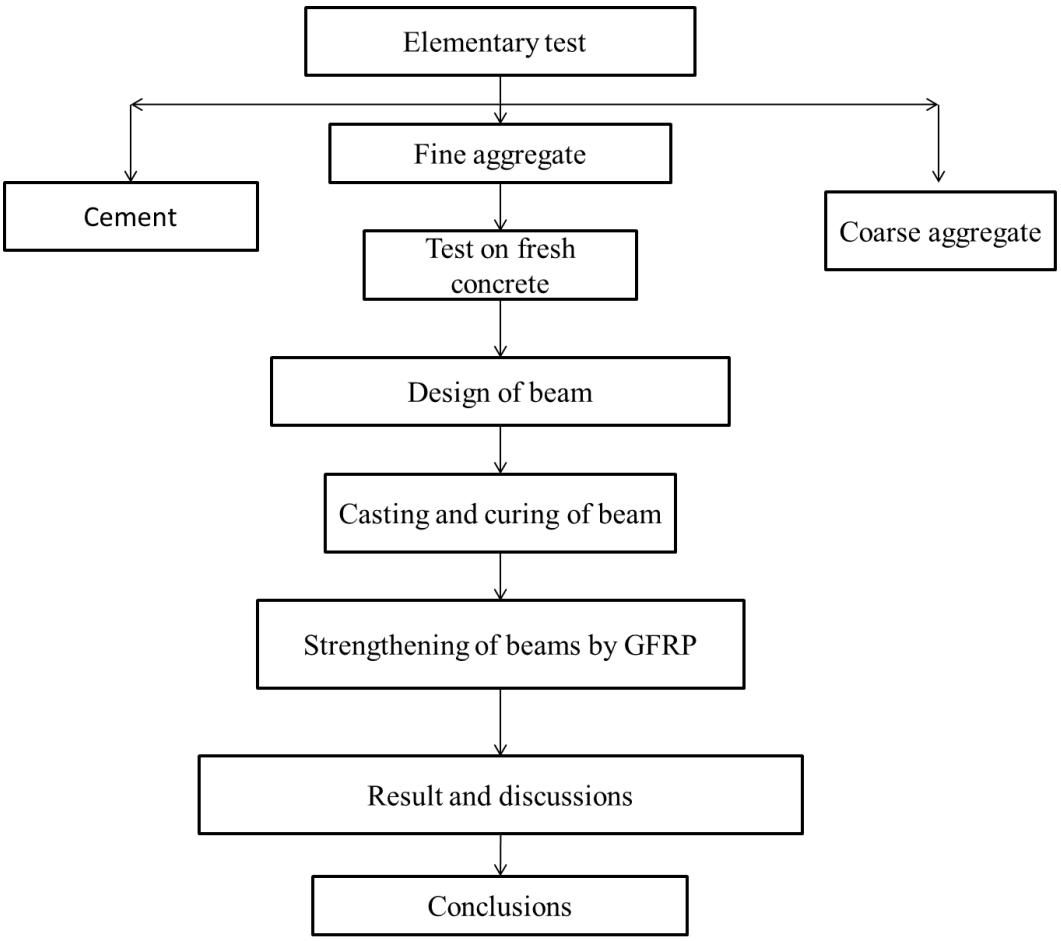
These beams were designed with different wrap materials, steel ratios and different wrap thickness. These beams were tested with a two point load system. The results were recorded as29% to 40% of increase in ultimate load for 3mm thick GRPF sheet and 29% to 129% of increase in ultimate load for 5mm thick GFRP sheet. In another experimental study, Reinforced Concrete (RC) inspected to record the performance on shear. The experiment was done with 9 Reinforced concrete beams in 3 categories. One set of beams were strengthened with vertical CFRP wraps, second set was strengthened with inclined CFRP wraps. The factors considered as key parameters were strength of the concrete, wrap orientation (900 & 450) CFRP thickness. The final test results exposed that the inclined CFRP configuration is more effective than vertical CFRP configuration. Sufficient shear strength was observed was observed in externally bonded CFRP wraps.In another experiment, the fire resistance of the structures were investigated in Reinforced concrete beams strengthened with Carbon Fiber Reinforced Polymer (CFRP) laminates. The specimen were tested under different fire protection systems and the results were recorded. Without coating the beam with fire protection system, the bond remained strong without any deformation till 23 min. after applying the fire protection materials at 25 mm thickness, the laminate remained without deformation till 60-89 min and at 40 mm thickness it remained till 137-167 min.

METHODOLOGY



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EXPERIMENTAL SETUP

Material used

Cement

According to our need we were tested the physical properties under the Indian standard specifications of the cement which is (OPC) ordinary Portland cement – 43, wonder cement grade is consonance with IS: 8112-1989. The test properties of OPC were mentioned in the table.

Table 1. Properties of cement

S.no	Description of test	Result obtained	Requirement of IS: 8112-1989
1	Initial setting time	152 Minutes	Min. 29 minutes
2	Final setting time	244 minutes	Max. 599 minutes
3	Specific gravity	3.123	3.13

Coarse aggregate

Specific test were performed in the accumulative of gruff as per IS: 2386-1963 it is extensive from 10 mm to 20 mm and temperate the coarse aggregates from the recognized quarry and 2.86 is the specific gravity of coarse aggregates.

Fine aggregates

As per IS: 383-1970 of aces aggregate physical properties is decisive by the use of mesh is about 4.74 mm is fleeting through river sand and 2.65 is its specific gravity. Zone II is for classify the fine aggregates.

Water

Water is a mandatory need for concreting, for that make sure the feasibility of water in line around the college campus.

Glass fibre reinforced polymer

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Fig: (a) (GFRP) Laminate of thickness 1.2 mm for strengthening of beams

For to enhance the RC beams GFRP (glass fibre reinforced polymer) is should be laminated about to 1.3 mm of thickness and manufacturer from Pondicherry, Tamil Nadu, India who supplies the laminates for GFRP with the use of adhesive is between the concrete and layers for better bonding.

Epoxy Resin

In various circumstance pre-polymers are able to refine. Typically, epoxy resins has a low molecular weights from the reaction of the epoxy "Resins" with polyamine "Hardener" and tends to form the thermosetting polymer.

Reinforcement

The dimension of the HYSD bar is Fe 415 of 11 mm diameter and 9 mm diameter bar were used for longitudinal reinforcement and also as a hanger bars. Fe 250 mild steel bars of 5 mm diameter for support clamps.

Mix proportion of concrete

According to our Indian standard 10262:1982 and 10262:2009 as per the mentioned rules mix proportioning of M30 grade of concrete were accomplished, while 0.44 was a mix design water cement ratio were take on and for current study mix proportion is also used.

Table 2.Mix proportion of M30 concrete

Content	Quantity		
Cement	405 kg/m^3		
Water	176 kg/m^3		
Fine aggregate	619.710 kg/m^3		
Coarse aggregate	1152.2 kg/m^3	19 mm	691.08 kg/m^3
		9 mm	460.04 kg/m^3
w/c ratio	0.44		

Casting of cubes

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BY using the compression machine testing on concrete 150 mm×150 mm× 150 mm size cubes were used and tested for 7 days after it take 28 days for healing.

Design of beams

In below mentioned table beam of design stuff is present:

Table 3: Mix proportion of M30 Concrete

1.	Length (L)	999 mm
2.	Breadth (B)	149 mm
3.	Gross depth (D)	150 mm
4.	Effective span (L_e)	899 mm
5.	Grade of main and hanger bars (F_y)	412 N/mm^2
6.	Characteristic strength of concrete (F_{ck})	32 N/mm^2
7.	Effective depth (d)	129 mm
8.	Number of beams	9

Fig (b): Loading

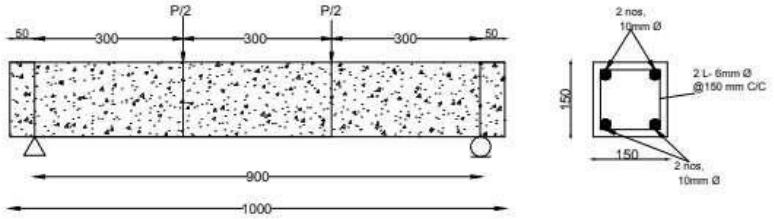

Diagram and Reinforcement detailing of the beam

Casting of beams

Limit state method helps to make blueprint for all the nine beams as per IS: 456-2000 code on account of the section must be strengthened and plywood mould were rehearsed under 150 mm×150 mm× 150 mm size. As per IS: 10262-1982 designed of concrete M30 grade was considered by using the machine concrete were mixed and the ratio for mix proportion is 1:1.15:2.83 ratio. Casting of beams will be understand by the following steps:

1. The mould should de-mould after a certain time it may take 24 hours for that first outright mould was oiled.
2. Position of block size is 20 mm for strengthen used cover blocks to distribute the even cover to the blocks.

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3. The mould is fully filled with concrete mix and let flow in layers by the tampering rods & vibrators is integrated and the process will plays until for blankness.
4. After 24 hours the bean was detached from the mould and then healed for 28 days
5. 6 beams were encased with glass fibre reinforced polymer (GFRP) laminate and 3 beams were casted out from 9 beams.

Fig (c): Beams After Casting

Strengthening of beams

In this experiment patterns for wrapping is about 1.2 mm of thickness in strengthened the beams and glass fibre reinforced polymer (GFRP)

1. UB (U-wrapped beam) is denominated by the strengthen beam for to strengthened in both shear and flexure. In two shear sides and on the bottom flexure sides for the entire length of the beam is wrapped with glass fibre reinforced polymer (GFRP).
2. FB (Flexure wrapped beam) is denominated by the strengthen beam for to strengthened the flexure only it is for 950 mm of wrapping over entire soffit of beam.
3. SFB (U-wrapped beam in shear zone) denominated by the strengthen beam for to strengthened only at the sides of beam in shear zone 300 mm of distance in 3 sides of beam is wrapped with glass fibre reinforced polymer (GFRP).

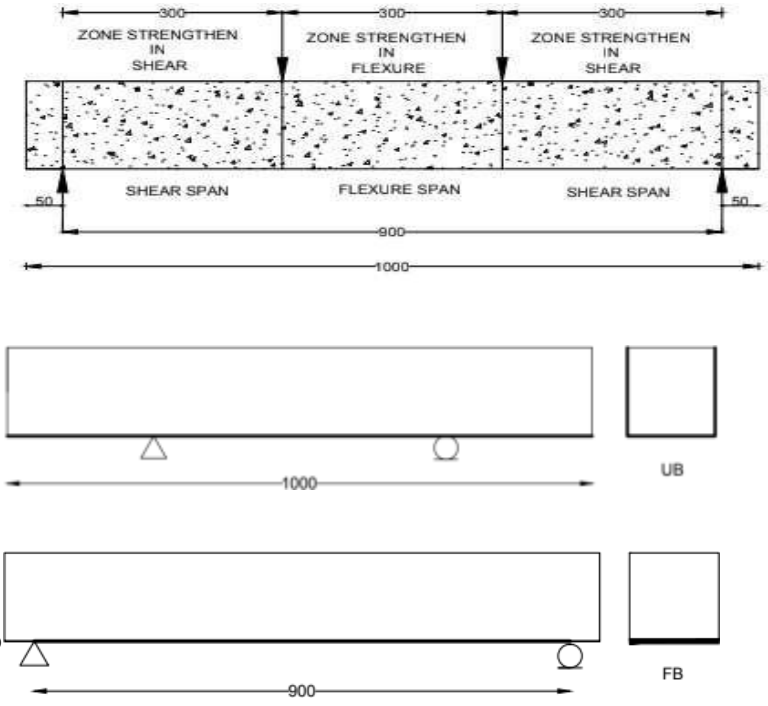

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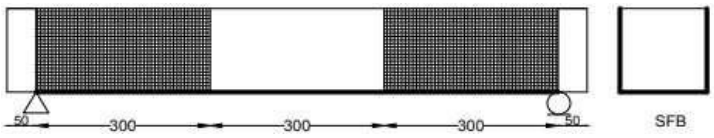
Fig (D): Beams After Casting

Test programme on beams

In universal testing machine (UTM) using a system of symmetrical two point loading for



to test the beam until it get failure before that 1.2 mm epoxy bonded glass fibre reinforced polymer (GFRP) laminates using epoxy resins for to strengthen the beams to determine the

ultimate load & deflection from the tested values after comparing the values of ultimate load and deflection to the obtained values.

Fig-E Loading setup

RESULT AND FINDINGS

Compressive strength of cubes

After 7- days compressive strength of cubes is mention in the table

Table 4. Compressive strength of cubes after 7-days

S.No	Specimen No.	Compressive Strength
1.	C 1	45 Mpa
2.	C 2	42.4 Mpa
3.	C 3	44.45 Mpa

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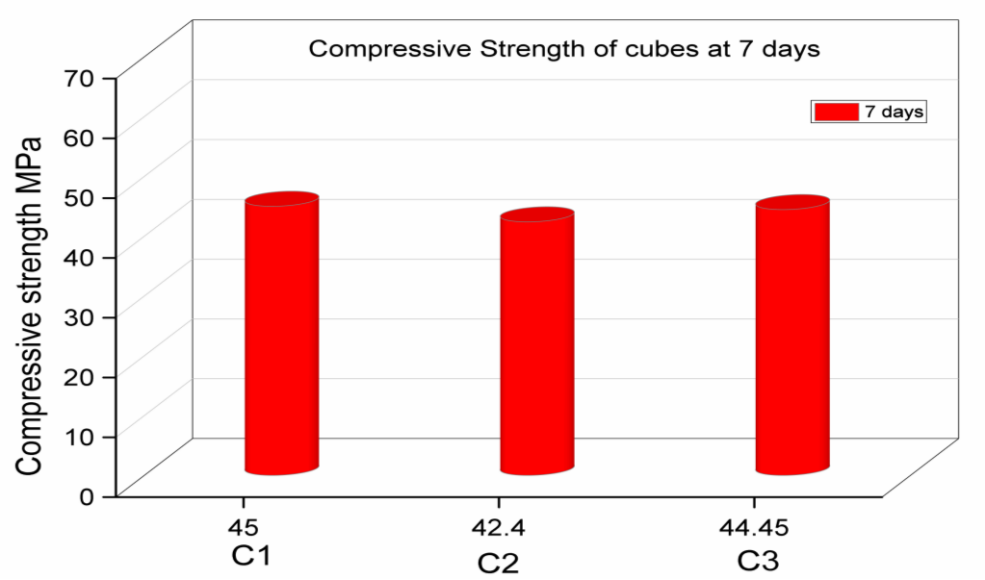
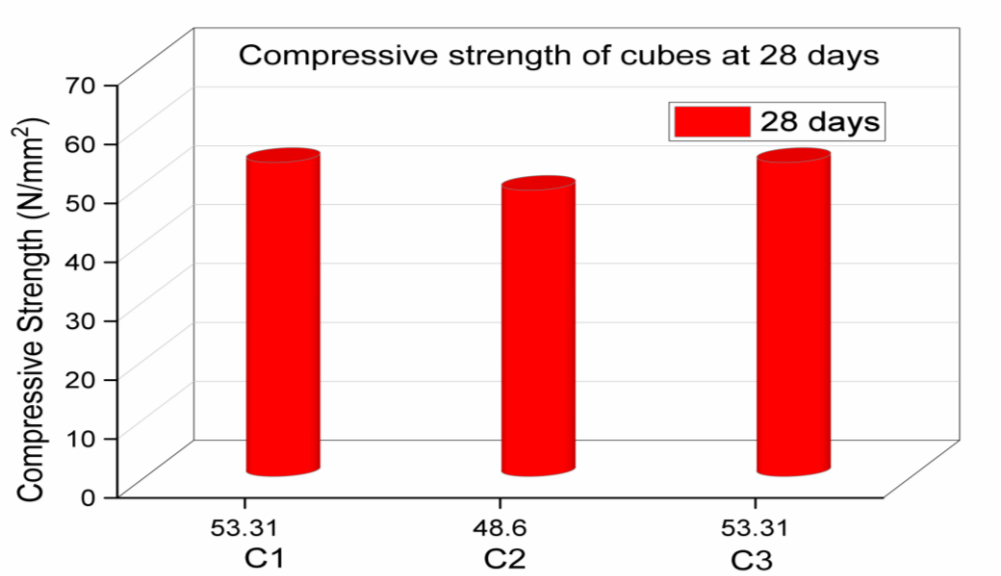


Graph 1 : Compressive Strength of Cube at 7 days

Table 5. Compressive strength of cube for 28 days

S.NO	SPECIMEN NO.	COMPRESSIVE STRENGTH
1.	C 1	53.31 Mpa
2.	C 2	48.6 Mpa
3.	C 3	53.31 Mpa



Graph 2 : Compressive strength of cube on 28 days = 51.82 Mpa

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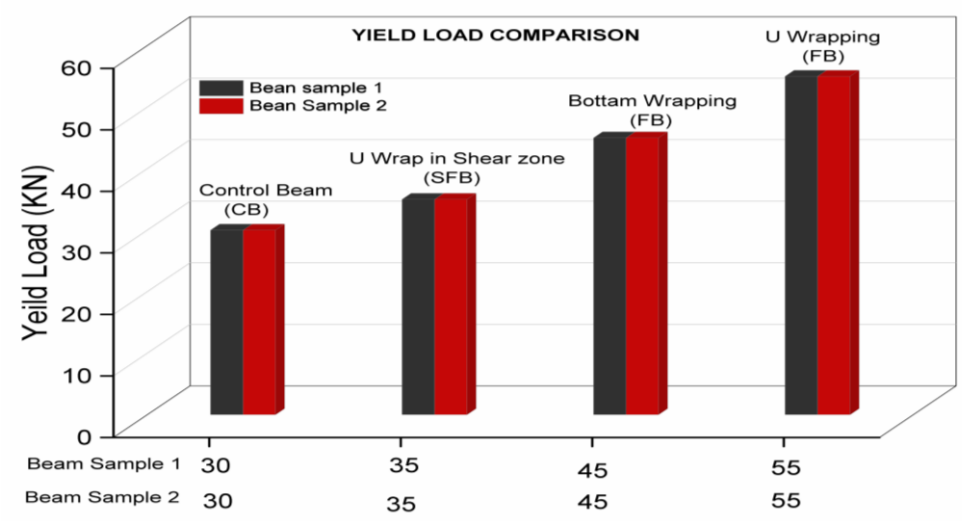
Load deflection behaviour

Observation of all loads deflection beam were noted and with respective to the beam load deflection behaviour of each beam was compared between wrapping it had a similar reinforcement.

Yield load

For all the beams initial load by the cracks were observed and noted. There is a variation in load and form from initial cracks in different beams. At 30 KN of load was attained for crack initiation in CB 1 & CB 2, at 35 KN of load was attained for crack initiation in SFB 1 & SFB 2, at 45 KN of load was attained for crack initiation in FB 1 & FB 2, at 55 KN of load was attained for crack initiation in UB 1 & UB 2.



Graph 3 : Yield load Comparison

Ultimate load carrying capacity

By found out the control beam and strengthen beam under the capacity of load carrying.

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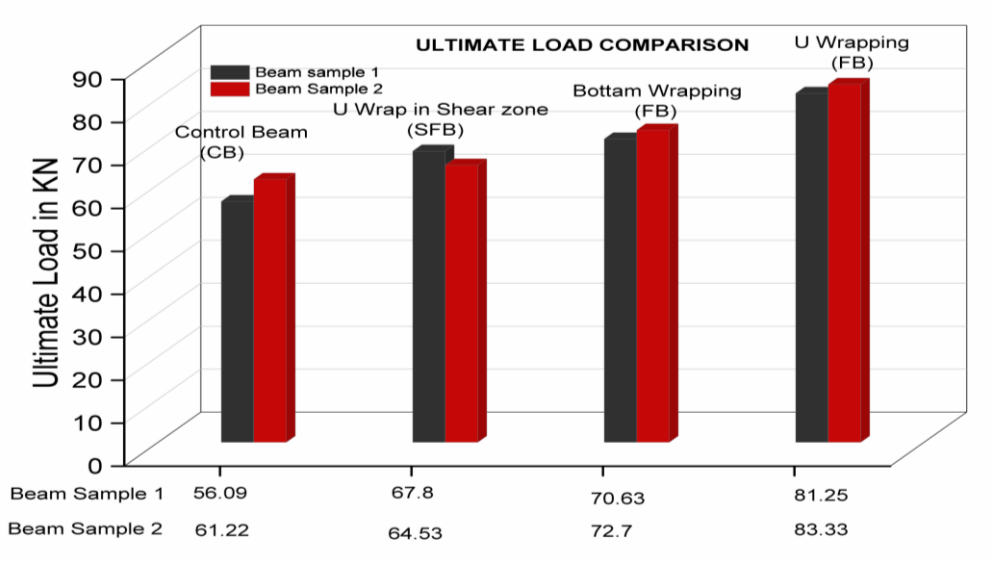
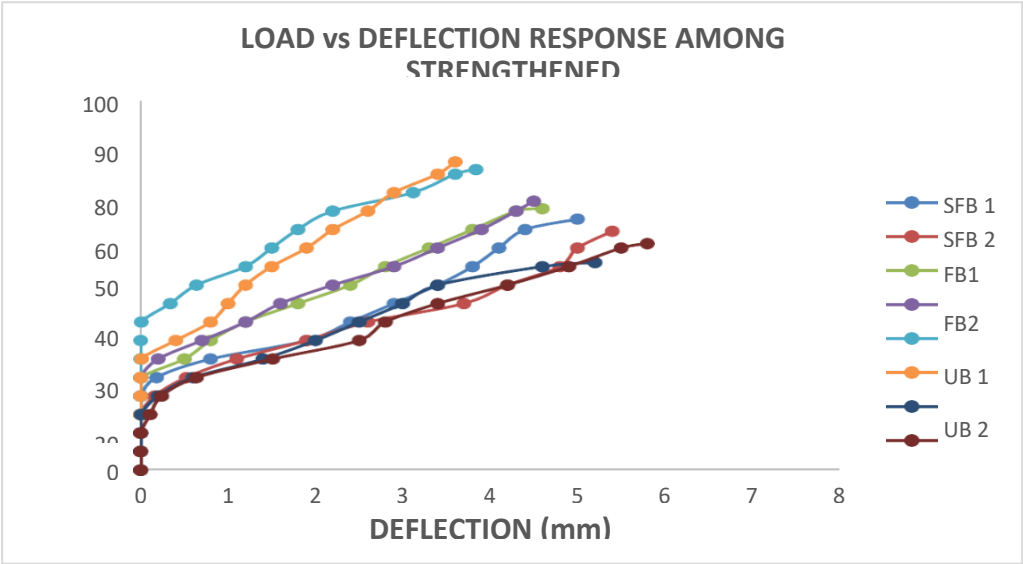


Graph 4 : Ultimate load Comparison

Ultimate load v/s load deflection

SFB, FB and UB are the beams were tested for strengthening which is was observed and mid of all the terms between load deflection under comparison. In the case of U-wrapping deflection of beam was diminished and add on the technique with glass fibre reinforced polymer (GFRP) the strength was increased by 12.82 %, 22.17% and 40.31 % when compared to the unstrengthen beam.



Graph 4 : Load Vs Deflection response among strengthened

CONCLUSION

Under various combination possibilities of beams were strengthened by glass fibre reinforced polymer (GFRP) three beams are the controlled beams from the nine beams and

remaining beams strengthen by the GFRP laminate. For to compare the values of ultimate load & deflection from the test values on the beam to the obtained values after testing conclusion is made by the obtain experimental test results and calculated strength values.

1. Higher load is observed from the strengthened beam with yield load & cracks compared to the controlled beams.
2. By glass fibre reinforce polymer (GFRP) technique of U wrapping is diminishing in the beam deflection is observed when compared to control beam.
3. The strength was increased by 12.82 %, 22.17 % & 40.31 % in unstrengthen beam but in strengthen beam U-wrapping (UB), U-wrapped beam in shear zone (SFB) and flexural wrapped beam (FB) strength was observed while concluding the unstrengthen beam there is an increase by strength were noted.
4. During the comparison of beam 9.36 % Flexural wrapped beam (FB) & 28 % U-wrapped (UB) under ultimate load carrying capacity U-wrapped beam in shear zone (SFB) is least.
5. Flexural wrapped beam (FB) is less under ultimate load carrying capacity when compared to UB beam.
6. U-wrap in shear zone (SFB) with respect to the load by 12 % through glass fibre reinforced polymer (GFRP) for to amplify the strength of the beam by supplying 24 % of GFRP strength is increased at the soffit of the beam and U-warp (UB) is strengthen by 42 %. Hence, concluded from the all above researches.

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