Flexural Behavior of Retrofitted Beams with Jute and Glass Fiber Woven Fabric

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Abstract:

Retrofitting is the trending technique in construction industry for conserving the old structure whose usable limit has been passed, building which got struck by any disaster or the structure load capacity required to be increased. In this work the fabric jacketing of beams is performed by two different techniques side wrapping and U-type wrapping and also three different configurations are used that are one glass-one jute layer, two glass-one jute layer and two glass-two jute layers. Total 14 beams are constructed in which two of them are control and tested up to ultimate failure and then other 12 beams are loaded up to 60% of ultimate load and then are retrofitted by above methods.

Keywords

Retrofitting; fabric jacketing; flexure testing; three-point testing

1. Introduction

Nowadays many structures are out of service due to completion of design life, overloading problem, hit by disasters, small defect in designing, etc. all these structures requires a little bit of the up gradation which can be achieved with the help of retrofitting them. Demolition and reconstructing is very uneconomical than the retrofitting because of this industry is going towards introducing new techniques to retrofitting. There are many methods of retrofitting out of which one of the most popular is FRP (Fiber Reinforced Polymer) jacketing. FRP jacketing is lightweight and easy to apply technique which gives considerable good tensile strength to element. The present work has used the combination of two types of FRP that are jute (also called as natural FRP), woven natural glass fiber.

2. Literature Review

Many of the researchers are contributing the work on retrofitting few of them are discussed in this review which is taken as foundation for this present work.

- Tara Sen and Jagannanth Reddy (2013) has wrapped beams with single layer of GFRP, CFRP and JFRP in both U-type and strip type configuration and found that ultimate flexural strength of U-type wrapped beam had increased by 125% in GFRP, 150% in CFRP and 62.5% in JFRP. Likewise when done with strap type wrapped beams than increment of 25% in JFRP, 50% in CFRP and 37.5% in GFRP is seen in flexural strength.
- Tara Sen (2016) had again repeated the work with sisal FRP, JFRP, GFRP, CFRP and constructed two types of samples one is full length U-type wrapped and other partial length U-type wrapped. The result had shown the increase in shear strength of SFRP, JFRP, GFRP and CFRP beams by 77%,66%, 89% and 83% respectively in full length U-type wrapped beam and 33%, 22%, 33% and 44% respectively in partial length U-type wrapped beams.
- Huang et. al. (2016) had done wrapping of two different reinforcement ration beams with natural Flax Fiber Reinforced beams in two condition one in which they wrapped unloaded beam and other after applying 80% yield load to the beam. After testing they found increase in ultimate load of FFRP wrapped beams ranging from 15.4% to 112.3%.

3. Experimental Procedure

In this 14 beams were constructed of size 130mm×230mm×1000mm in which two beams were control beams to check the ultimate load carrying capacity. Rest of the 12 were wrapped by two schemes that were side wrapping and U-type wrapping in which further divided into three types of layers of JFRP and GFRP is used for retrofitting beams. Before wrapping beams the 60% of failure load is applied to them after which they were retrofitted, wrapped and tested. The following were the steps done in this work:-

1. Collect information about material which will be used in casting and calculate theoretical estimations for concrete mix.
2. Cast 14 beams by using M25 grade concrete mix and Fe 500 grade steel.
3. Found ultimate failure load by two control beams.
4. The remaining were loaded up to 60% of ultimate failure load.

5. And after which beams were retrofitted with JFRP and GFRP in different combinations.

4. Materials Used

4.1. Cement:

Ordinary Portland cement is used of grade 43 as per IS: 8112-2013. With calculated specific gravity, initial setting time, final setting time and consistency as 3.12, 123minutes, 270minutes and 28% respectively.

4.2. Fine Aggregates

Sand used is of zone second according to IS: 383-1970. With calculated specific gravity, water absorption and fineness modulus as 2.63, 0.80 and 3.92 respectively.

4.3. Coarse Aggregates

Specific gravity of coarse aggregate used is 2.69 with net water absorption of 0.85 and fineness modulus of 6.10.

4.4. Epoxy

Epoxy used in this work is Dr. Fixit 211epoxy to bond the concrete and fibers together. Epoxy was excellent in adhesion, good in bond strength, had low shrinkage, water resistance, non-toxic and highly durable.

5. Mix Proportion design

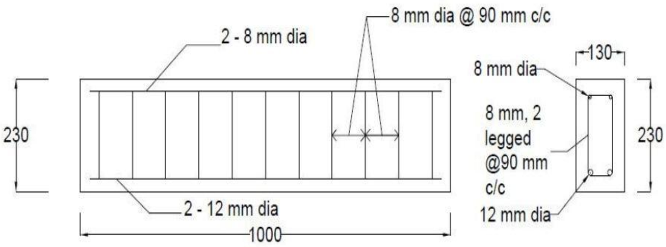
The mix design of concrete is done as per IS: 10262-2009. The ratio of mix design is shown below in Table-1.

Table-1 Mix proportion of M25 grade concrete used in the study

Constituent	Weight (kg/m^3)	Ratio
Water	191.5	0.45
Cement	425.5	1
Fine aggregate	655.8	1.54
Coarse aggregate	1148.6	2.70

6. RCC Beam Design and Casting

Using M25 grade concrete and Fe 500 steel, 14 beams are made of the following configuration shown below in Figure-1



Figrure-1 Reinforcing details and dimension (in mm) of beams

After skeletons were placed in the moulds of given internal dimension and concreting was done. Needle vibrator was used in compaction. After placing concrete, moulds are left for 24 hours before. De-moulding is done after 24 hours and specimens are cured by help of jute bags for 28 days as shown in Figure-2.

Figure-2 Figure showing processes of casting

7. Testing Setup

All the beams were tested with the help of Universal Testing Machine. The single point load is applied at L/2 from the supports and loading rate is nearly 0.1kN/sec is applied on the beam. The testing setup is shown in Figure-3.

Figure-3 Image of testing setup

8. Retrofitting of Beams

After applying 60% of failure load on 12 beams, the surface of the beams were made from any loose material and epoxy was applied and wrapping is done of beams which is shown in Figure-4. The different forms of wrapping are explained in Table-2.

Figure-4 Retrofitting of beam is done by U-type and side wrapping by applying epoxy on JFRP and GFRP

Table-2 Types of layers and wrapping schemes for retrofitting

Beam name	Wrapping type	Layer configurations	Beam type
C1	-	-	-
C2	-	-	-
B1-SW^A	Side	1-Jute 1-Glass	Type-1
B1-SW^B	Side	1-Jute 1-Glass	
B2-SW^A	Side	1-Jute 2-Glass	Type-2
B2-SW^B	Side	1-Jute 2-Glass	
B3-SW^A	Side	2-Jute 2-Glass	Type-3
B3-SW^B	Side	2-Jute 2-Glass	
U1-SW^A	U-type	1-Jute 1-Glass	Type-1
U1-SW^B	U-type	1-Jute 1-Glass	
U2-SW^A	U-type	1-Jute 2-Glass	Type-2
U2-SW^B	U-type	1-Jute 2-Glass	
U3-SW^A	U-type	2-Jute 2-Glass	Type-3
U3-SW^B	U-type	2-Jute 2-Glass	

9. Results

Load-deflection behavior of every beam was noted with the help of testing setup mentioned in Section 7. Firstly the control beams C1 and C2 were tested up to the failure mode 123kN and 127kN respectively. So average of failure load was choose which was125kN and 60% of 125kN is nearly 70kN to which other beams were subjected.

9.1. Ultimate load and deflection values

The average ultimate load and deflection of same type of beams were calculated and comparison is made which is shown in Table-3.

Table-3 Ultimate load and deflection of beams with percentage increase in ultimate load and deflection according to control beam

Beam	Ultimate Load (kN)	Ultimate deflection (mm)	% increase in ultimate load	% increase in ultimate deflection
CB	125	3.217	-	-
B1-SW	135	3.378	8	5
B2-SW	140	3.700	12	15.01
B3-SW	147	3.869	17.6	20.26
B1-UW	143	3.631	14.4	12.86
B2-UW	153	4.467	22.4	38.85
B3-UW	162	4.602	29.6	43.05

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9.2. Load vs. Deflection behavior of beams

The load-deflection graph of every beam was made manually by recording the deflection at every kilo Newton with the help of the dial gauge which was arranged at lowest point the mid span with help of a stick and epoxy. The deflection had increased up to some extent by retrofitting the beams. The graphs of all beams had shown nearly a straight line behavior for the first 60kN load afterwards few curved bend is seen in the graphs indicating the yielding had started in the steel reinforcement by deflection starts to move at the faster rate than the initial stage. After reaching to an ultimate stage the load reduced dramatically with a little increase in the deflection was seen after which failure of beams occurred and load application by UTM machine will stop. The average load vs. deflection graph of every type of beam is shown in Figure -5 for comparison.

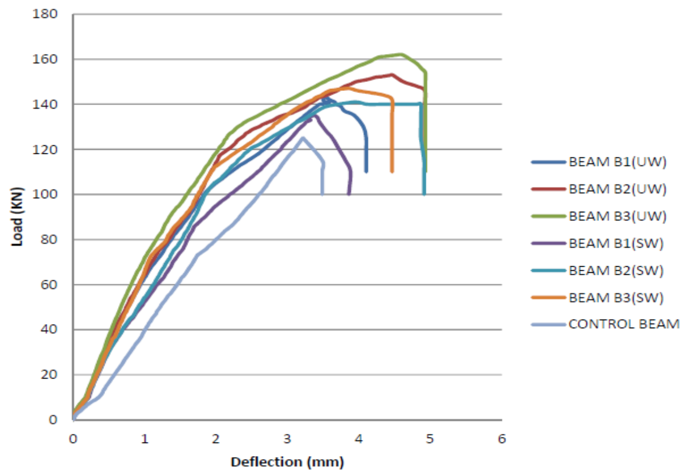

Figure-5 Load-deflection graph of retrofitted and control beams

9.3. Ductility of Beams

Ductility of beams is measured by the help of ductility factors which is defined as the ratio of ultimate load deflection to yield load deflection. Yield load deflection is taken as the deflection at which first visible crack is seen in the element. The ductility factor of all type beams used in this work is shown in Table-4.

Table-4 Ductility factor of beams

Beams	Ductility Factor
CB	1.71
B1-SW	1.58
B2-SW	1.36
B3-SW	1.31
B1-UW	1.39
B2-UW	1.29
B3-UW	1.27

9.4. Crack Patterns of beams

Crack in the beams were observed very carefully and found that control beam was failed in the mixed flexo-shear failure behavior whereas the entire retrofitted beam had shown failure in pure flexure. Few of the beams also shown de-bonding at ultimate failure showing elastic modulus of concrete is more than wrapping. The ultimate crack patterns of the beams are shown Figure -6 to 12.

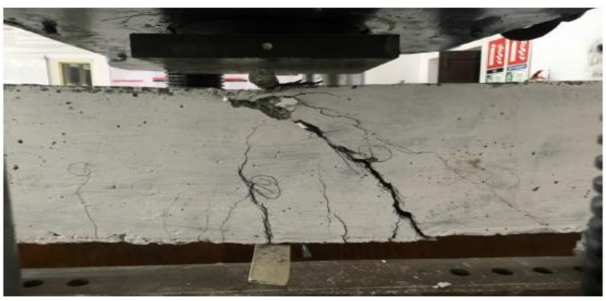

Figure-6 Crack patterns in CB at ultimate load

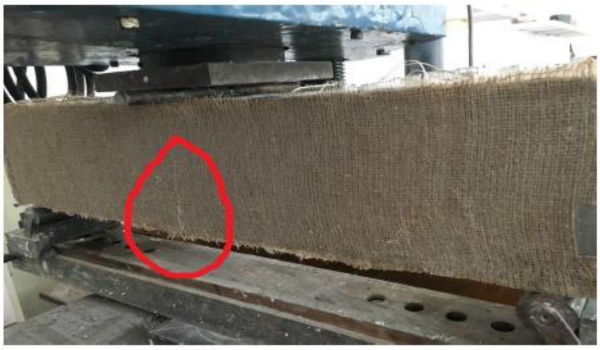

Figure-7 Single flexure crack failure in B1-SW beam

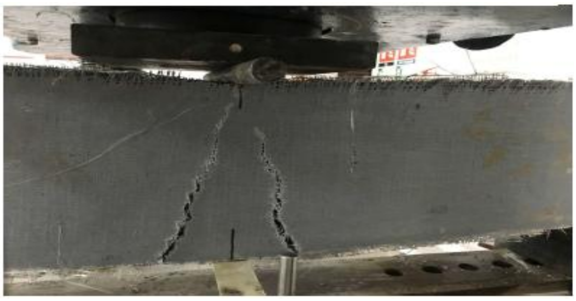

Figure-8 Crack pattern in B2-SW beam

Figure-9 De-bonding of the wrapping at failure in B3-SW beam

Figure-10 Crack pattern in B1-UW at failure

Figure-11 Crack pattern in B2-UW at failure

Figure-12 Crack pattern in B3-UW at failure

10. Conclusions

The following conclusion can be drawn from the above work:-

1. There is increase in the ultimate load and deflections capacities of all retrofitted beams as compared to control beams.
2. The beams named B1-SW, B2-SW and B3-SW retrofitted with wrapping on sides with Type-1, Type-2 and Type-3 layering respectively, showed increase in ultimate load capacity of 8%, 12% and 17.6% respectively. These beams also showed increase in maximum deflection by 5%, 15.01% and 20.26% respectively when compared with control beam.
3. The beams named B1-UW, B2-UW and B3-UW retrofitted with three side U-type wrapping technique using Type-1, Type-2 andType-3 layering scheme respectively, showed increase in ultimate load carrying capacity of 14.4%, 22.4% and 29.6% respectively. These beams also showed increase in ultimate deflection by 12.86%, 38.85% and 43.05% respectively when compared with control beam.
4. It can be concluded that U-Wrapping technique showed better load deflection behaviour than Side-Wrapping technique. Also, the use of textile jute and glass FRP in continuous full length U-wrapping had helped in delaying the growth of crack formation, as it is evident from the experiment that the first crack appeared at much higher load when compared to control beam. The retrofitted beams carried huge deflection before failure; this showed their ductile behaviour and provided sufficient warning before failure.
5. It is evident from the experiment that with the increase in number of layers of jute and glass woven fabric, the strengthening effect increased. Hence, it can be concluded that using jute fabric and glass fabric in alternate layers as retrofitting material for retrofitting of damaged or weak existing beams, is very much capable of increasing the flexural as well as shear strength of the beam.

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