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Strengthening of R.C.C. Beam- using Different Glass Fiber

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Abstract: Worldwide, a great deal of research is currently being conducted concerning the use of fiber reinforced polymer wraps, laminates and sheets in the repair and strengthening of reinforced concrete members. Fiber-reinforced polymer (FRP) application is a very effective way to repair and strengthen structures that have become structurally weak over their life span. FRP repair systems provide an economically viable alternative to traditional repair systems and materials. Experimental data on load, deflection and failure modes of each of the beams were obtained. The detail procedure and application of GFRP sheets for strengthening of RC beams is also included. The effect of number of GFRP layers and its orientation on ultimate load carrying capacity and failure mode of the beams are investigate.

Keywords: FRP, GFRP, Retrofitting.

I. INTRODUCTION

1.1General

There are considerable number of existing concrete structures in India that do not meet current design standards because of inadequate design and construction or need structural up gradation to meet new seismic design requirements because of new design standards, deterioration due to corrosion in the steel caused by exposure to an aggressive environment and accident events such as earthquakes . Inadequate performance of this type of structures is a major concern from public safety standpoint. That is why reinforced concrete structures often have to face modification and improvement of their performance during their service life. In such circumstances there are two possible solutions: replacement or retrofitting. Full structural replacement might have determinate disadvantages such as high costs for material and labour, a stronger environmental impact and inconvenience due to interruption of the function of the structure e.g. traffic problems. When possible, it is often better to repair or upgrade the structure by retrofitting.

Retrofitting have become the increasingly dominant use of the material in civil engineering, and applications include increasing the load capacity of old structures that were designed to tolerate for lower service loads than they are experiencing today, seismic retrofitting, and repair of damaged structures.Concrete structures deteriorate with time, a process that becomes much faster in aggressive environmental conditions. Broadly, methods to repair them can be classified under structural repair and nonstructural repair. Structural repair is carried out by repair, renovation and retrofitting of the entire system as a whole for structural strengthening to carry additional loads or for retrofitting.

Glass Fibers are produced from wild range of glass types, E, S, R glass, which differ only in the proportioning of their contents. Such glass fibers are weak in alkali resistance. To overcome this problem, surface coating of glass fiber is used to reduce alkali effect and increase wearing resistance of fibers. Such glass fibers are known as alkali-resistance glass fiber. Alkali resistant glass fibers give good results when reinforced with alkaline environment of concrete. Nowadays Alkali-resistance glass fibers are used in FRC

Many of the existing reinforced concrete structures throughout the world are in urgent need of rehabilitation, repair or reconstruction because of deterioration due to various factors like corrosion, lack of detailing, failure of bonding between beam-column joints, increase in service loads etc, leading to crack, loss of strength, deflection, etc. The recent developments in the application of the advanced composites in the construction industry for concrete rehabilitation and strengthening are increasing on the basis of specific requirements, national needs and industry participation. The need for efficient rehabilitation and strengthening techniques of existing concrete structures has resulted in research and development of composite strengthening systems.

One of the challenges in strengthening of concrete structures is selection of a strengthening method that will enhance the strength and serviceability of the structure while addressing limitations such as constructability, building operations, and budget. Structural strengthening may be required due to many different situations.

- Additional strength may be needed to allow for higher loads to be placed on the structure. This is often required when the use of the structure changes and a higher load carrying capacity is needed. This can also occur if additional mechanical equipments, filing systems, planters, or other items are being added to a structure.
- Strengthening may be needed to allow the structure to resist loads such as additional floor loads, inadequate concrete strength & others i.e. wind, seismic blast etc that were not considered in the original design.
- Additional strength may be needed due to deficiency in the structure's ability to carry the original design loads. Deficiencies may be the result of deterioration (e.g., corrosion of steel reinforcement and loss of concrete section), structural damage (e.g., vehicular impact, excessive wear, excessive loading, and fire), or errors in the original design or construction.

The majority of structural strengthening involves improving the ability of the structural element to safely resist one or more of the internal forces caused by loading: shear and axial.

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Strengthening is accomplished by increasing the capacity of member to resist the magnitude of these forces.

The selection of the most suitable method for strengthening requires careful consideration of many factors including the following engineering issues:

- Magnitude of strength increase;
- Effect of changes in relative member stiffness;
- Size of project (methods involving special materials and methods may be less cost-effective on small projects);
- Environmental conditions (methods using adhesives might be unsuitable for applications in high-temperature environments; external steel methods may not be suitable in corrosive environments).
- In-place concrete strength and substrate integrity (the effectiveness of methods relying on bond to the existing concrete can be significantly limited by low concrete strength);
- Dimensional/clearance constraints (section enlargement might be limited by the degree to which the enlargement can encroach on surrounding clear space);
- Accessibility;
- Availability of materials, equipment, and qualified contractors;
- Operational constraints (methods requiring longer construction time might be less desirable for applications in which building operations must be shut down during construction);
- Construction cost, maintenance costs, and life-cycle costs; and
- To verify the existing capacity by load test or evaluate new techniques and materials.

II. STRENGTHENING USING FRP COMPOSITES

Only a few years ago, the construction market started to use FRP for structural reinforcement, generally in combination with other construction materials such as wood, steel, and concrete. FRPs exhibit several improved properties, such as high strength-weight ratio, high stiffness-weight ratio, flexibility in design, non-corrosiveness, high fatigue strength and ease of application. The use of FRP sheets or plates bonded to concrete beams has been studied by several researchers. Strengthening with adhesive bonded fiber reinforced polymers has been established as an effective method applicable to many types of concrete structures such as columns, beams, slabs, and walls. Because the FRP materials are non-corrosive, non-magnetic, and resistant to various types of chemicals, they are increasingly being used for external reinforcement of existing concrete structures.

From the past studies conducted it has been shown that externally bonded carbon fiber-reinforced polymers (CFRP) can be used to enhance the flexural, shear and tensional capacity of RC beams. Combined with high tensile strength-weight ratio and stiffness, the flexible glass fiber sheets are found to be highly effective for strengthening of RC beams. The use of fiber reinforced polymers (FRPs) for the rehabilitation of existing concrete structures has grown very rapidly over the last few years. Research has shown that FRP can be used very efficiently in strengthening the concrete beams weak in flexure, shear and torsion. Unfortunately, the current Indian concrete design standards (IS Codes) do not include any provisions for the flexural, shear and torsional strengthening of structural members with FRP materials. This lack of design standards led to the formation of partnerships between the research community and industry to investigate and to promote the use of FRP in the flexural, shear and torsional rehabilitation of existing structures. FRP is a composite material generally consisting of high strength carbon, aramid, or glass fibers in a polymeric matrix where the fibers are the main load carrying element. Among many options, this reinforcement may be in the form of preformed laminates or flexible sheets. The sheets are either dry or pre-impregnated with resin and cured after installation onto the concrete surface. This installation technique is known as wet lay-up. FRP materials offer the engineer an outstanding combination of physical and mechanical properties, such as high tensile strength, lightweight, high stiffness, high fatigue strength, and excellent durability. The lightweight and formability of FRP reinforcement make FRP systems easy to install. Since these systems are non-corrosive, non-magnetic, and generally resistant to chemicals, they are an excellent option for external reinforcement. Strengthening with externally bonded FRP sheets has been shown to be applicable to many types of RC structural elements. FRP sheets may be adhered to the tension side of structural members (e.g., slabs or beams) to provide additional flexural strength. They may be adhered to web sides of joists and beams or wrapped around columns to provide additional shear strength. They may be wrapped around columns to increase concrete confinement and thus strength and ductility.of columns. Among many other applications FRP sheets may be used to strengthen concrete and masonry walls to better resist lateral loads as well as circular structures (e.g., tanks and pipelines) to resist internal pressure and reduce corrosion. As of today, several millions of square meters of surface bonded FRP sheets have been used in many strengthening projects worldwide.

MATERIALS

1.1. Fiber System

The fiber system used in an FRP pultruded part can consist of different types and architectures of fiber materials. The raw fiber is processed and supplied either in strand form on a spool and known as roving or tow, or in broad goods form on a roll and known as mat, fabric, veil, or tissue. Two primary types of fiber systems are used when the hand-layup method is used for FRP strengthening: unidirectional tow sheets and uni-or multidirectional woven or stitched fabrics. Carbon and E-glass are the most commonly used fiber types; however, some manufacturers do supply aramid fiber fabrics and also hybrid fiber fabrics.

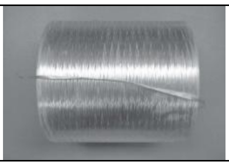
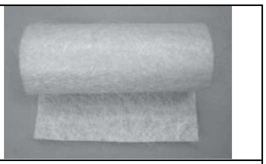
- Fiber Rovings

Individual continuous fiber filaments are bundled, generally without a twist, into multifilament strands known as rovings that are used in the pultrusion process either as is or in fabrics produced from rovings. In the United States, roving quantity is traditionally measured in units of yield (yd/lb).

Roving is produced in yields of 56, 62, 113, 225, 250, 450, 495, 650, and 675. Not all producers manufacture all yields. The number of filaments in an individual roving with a specific yield depends on the fiber diameter of the filament. The most common roving used in pultruded parts is a 113 yield roving, which has approximately 4000 filaments, usually having a diameter of 24 fm (93 X 10-3 in.) each. Figure 2.1 shows a spool of 113 yield glass fiber roving.

- Fiber Mats

Continuous filament mat (CFM) also referred to in the United States as continuous strand mat, is the second most widely employed glass fiber product used in the pultrusion industry. CFM is used to provide crosswise (CW) or transverse strength and stiffness in plate like parts or portions of parts (e.g., the flange of a wide-flange profile). CFMs consist of random, swirled, indefinitely long continuous glass fiber filaments held together by a resin-soluble polymeric binder. They are different from copped strand mats (CSMs), which consist of short [1 to 2 in. (25 to 50 mm)] fibers held together in mat form by a resin-soluble binder which are used mainly in sheet molding compounds.

	
Fi2.1 113 yield glass roving	Fig 2.2 Glass continuous filament mat

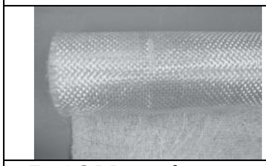



Fig 2.3 Woven glass roving combination fabric	Fig 2.4 Stitched glass fiber fabric

- Fiber Fabric

Fiber fabric materials for pultrusion are generally of two types. One type is a woven roving fabric; the other type is a stitched roving fabric. Woven roving is used routinely in hand-layup applications such as boat building and is supplied in weights between 200 to 1600 g/m2and has fiber orientations of 0° and 90°. The percentage of 0° and 90° fibers [known as the warp and the weft (or fill) directions in the textile industry] depends on the weave pattern. Most woven fabrics made for use in pultrusion are of the plain or square pattern, with almost equal percentages of fibers in the two directions.

To use a woven roving in a pultrusion process, it needs to be attached to a mat (usually, a chopped strand mat) to prevent it from distorting when pulled. Either powder bonding, stitching with a polyester or glass yarn, or needling are used to attach the woven fabric to the mat, which is then known as a combination fabric. Many different combinations of woven roving weights and mat weights are available. Commonly used types are (600-g/m2 woven roving with a 300-g/m2 mat). A close-up of a woven roving combination fabric is shown in Fig. 2.3The other type of fabric type that is used in pultrusion is a stitched fabric where the unidirectional layers of rovings in different directions are stitched together with or without a chopped mat. Popular types of stitched fabrics are biaxial (having equal percentages of 0° and 90° or +45° and -45° fiber orientations) and triaxial (having fibers in the 0°, +45°, and -45° fiber orientations). +45° and -45° fiber orientations are used to give a pultruded part high in-plane shear strength and stiffness properties. Unidirectional stitched fabrics in which the fibers in one direction are stitched to a mat can also be obtained. These are particularly useful when 90° fiber orientation is needed in a pultruded part to give it high transverse strength and stiffness. For unique applications, unbalanced stitched fabrics can be obtained. As noted previously, it is important to ensure that the resulting layup is both symmetric and balanced when using stitched and combination-stitched fabrics. A close-up of a stitched fabric is shown in Fig. 2.4.

III. EXPERIMENTAL WORK

1.2. Experimental Work

The experimental work consists of casting of four sets of reinforced concrete (RC) beams having grade M30, cross-sectional dimensions of 150mm x 200mm and 1000mm length. We provided 2-12mm Ø bottom reinforcement and 2-8mm Ø top with 6mm Ø vertical stirrups @ 160mm c/c. The strengthening of the beams using GFRP sheet is done with three different configurations namely both side wrap, bottom wrap & U wrap.

The experimental study consists of casting of four sets of reinforced concrete (RC) beams of grade M30, Total 30 no. of RC beam are cast and curing for 28 days. First set of (3 no.) RC beams designated as control RC beams (SET I). Second set of (9 no.) RC beams (SET II); all are strengthened using single GFRP mat wrap, (for three beams both side wrap, three beam bottom wrap, and three beams U shape wrap), Third set of (9 no.) RC beams (SET III); all are strengthened using Double GFRP mat wrap, (for three beams both side wrap, three beams bottom wrap and three beams U shape wrap). Fourth set of (9 no.) RC beams (SET IV) are strengthened using Woven Roving GFRP mat wrap, (for three beams both side wrap, three beams bottom wrap and three beams U shape wrap).

1.3. Casting of Beams

Four sets of beams as mentioned in section 4.1 are identical. Reinforcement detail of beam and section is shown in Fig 3.1& 3.2 respectively.

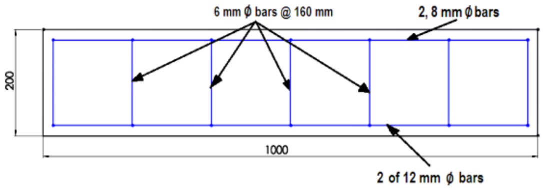


Fig .3.1 Reinforcement Detail of Beams

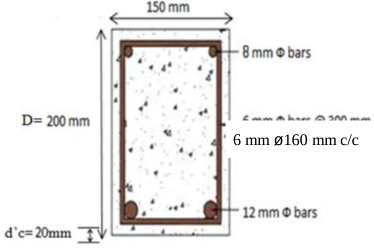


Fig.3.2 Section of Beams

1.4. Materials used for Casting of beams

- Cement

Ordinary Portland cement (OPC) of 53 grade is used for the casting of beams. The physical properties of the cement are tested in accordance with Indian Standard specifications (IS: 4031-1968) to know its suitability. The results of various physical tests on cement are given in Table 4.1.

Table 3.1: Physical Properties of Cement

Sr. No.	Type of Test	Results For OPC 53 Grade
1	Fineness of Cement (%)	8.5 %
2	Standard Consistency (%)	33
3	Initial Setting Time (min)	48
4	Final Setting Time (min)	240
5	Specific gravity	3.15
Compressive strength:- Cement : Sand (1:3)		
1	3 days	24.5 N/mm^2
2	7 days	35.0 N/mm^2
3	28 days	53.5 N/mm^2

- Course Aggregate

Locally available river sand, basalt stone chips were used for preparation of concrete. Machines crushed locally available hard basalt, well graded 12.5 mm and down size were used. Some of their properties were tested as per IS Code and the values are given in table below.

Table No. 3.2: Properties of Course Aggregate

Sr. No.	Properties	Value
1.	Specific Gravity	3.05
2.	Fineness Modulus	3.44
3.	Water Absorption (24 hours)	0.5%

- ○ Sieve Analysis

Table No. 3.3: Sieve Analysis of Course Aggregate

Sieve size in mm	% mass retained	Cumulative%	% Passing
20	18.870	18.870	81.130
16	25.000	43.870	56.130
12.5	42.370	86.240	13.760
10	9.000	95.240	4.760
4.75	4.760	100.000	0.000
Total	100.000	344.220	-

- Fine Aggregate

Locally available river sand passing through 4.75mm sieve as per IS: 383 provisions were used as fine aggregates.

Table No.3.4: Properties of Fine Aggregate (Sand)

Sr. No.	Properties	Value
1.	Specific Gravity	2.85
2.	Fineness Modulus	2.790
3.	Water Absorption (24 hours)	2.5%

- ○ Sieve Analysis

Table No.3.5: Sieve Analysis of Fine Aggregate

Sieve Size In mm	% mass retained	Cumulative %	% Passing
4.75 mm	3.800	3.800	96.200
2.36 mm	6.200	10.000	90.000
1.18 mm	14.400	24.400	75.600
600 micron	17.600	42.000	58.000
300 micron	53.100	95.100	4.900
150 micron	8.600	103.700	-
Total	100.000	279.000	-
Fineness Modulus		2.790	

Referring to 600 micron sieve, the percentage passing is 58.00 % which confirm that fine aggregate belongs to Zone –II as per Is: 383-1970.

- Water

The water from supply mains was used for the preparation of concrete and its subsequent curing.

- Reinforcing Steel

We provided 2-12mm Ø bottom reinforcement and 2-8mm Ø with 6mm Ø vertical stirrups @ 160mm c/c.

- Form Work

Ply is used to prepare formwork for beam of size 150mm x 200mm and 1000mm long. The form work is thoroughly cleaned and all the corners and junctions were properly sealed to avoid leakage of concrete through small openings. Shuttering oil was then applied to the inner face of the form work. The reinforcement cage is then placed in position inside the form work carefully keeping in view a clear cover of 20 mm for the top and bottom bars as shown in Fig 4.4

Fig3.3: Formwork for beams

1.5. Concrete Design Mix (M 30)

1 Grade of concrete : M30
2 Cement : Ordinary Portland cement (OPC) of 53
3 Target Strength[f_c] = f_{ck} + (1.65 x S)
= 30 + (1.65 x 5)
= 38.25 N/mm^2
4 Specific Gravity
Cement : 3.15
Sand : 2.85

Aggregate : 3.05

5 Cement content (Taken for Design] : 300 Kg/m^3

6 W/C ratio : 0.45

7 Water content : 135 Kg/m^3

8 Sand Content : 877.529 Kg/m^3

$$1000 = 135 + \frac{300}{3.15} + \frac{fa}{0.4 * 2.85}$$

9 Coarse Aggregate : 1408.664 Kg/m^3

$$1000 = 135 + \frac{300}{3.15} + \frac{Ca}{0.6 * 3.05}$$

10 Final Mix Proportion

Cement (Kg/m^3)	**Sand** (Kg/m^3)	**Coarse Aggregate** (Kg/m^3)	**Water** (Kg/m^3)	**Chemical**
300	877.52	1408.66	135	1 % of Cement by Weight

11 Concrete Design Mix Ratio

1	**2.925**	**4.696**	**0.45**	**3 Lit**

1.6. Experimental Setup

All the specimens are tested in Universal testing machine (UTM) and the deflection will be check by using (LVDT) machine. The testing procedures for the all specimens are same. After the curing period of 28 days is over, control beams (SET I) are washed and its surface is cleaned for clear visibility of cracks. Where other sets of beams (SET II, SET III, SET IV), are strengthened by GFRP. The load arrangements for testing of all sets of beam is consist of two-point loading as shown in Fig 3.5

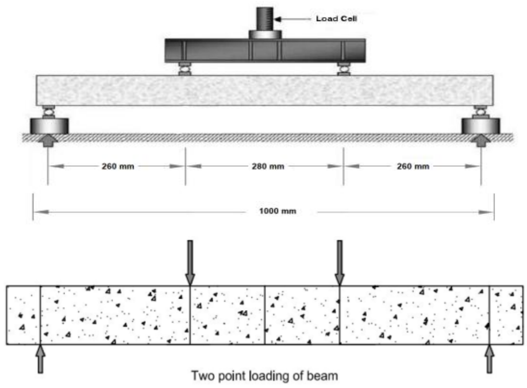


Fig. 3.5: Experimental setup for testing of beams

IV. EXPERIMENTAL TEST RESULT

1.7. Testing Procedure

Before testing the member was checked dimensionally and detail visual inspection made with all information carefully recorded. After setting all, the load was increased up to the failure of beam and deflection was recorded at each stage, and a load/deflection plot was prepared.

1.8. Failure Mode

Failure modes have been observed in the experiments of RC beams strengthened by GFRP. The GFRP strengthened beams and the control beams are tested to find out their ultimate load carrying capacity. It is found that the control beams (SET I) failed in shear. In control beams (SET I) the shear cracks started at the supports. As the load increased, the crack started to widen and propagated towards the location of loading. The cracking patterns show that the angle of inclined crack with the horizontal axis is about 45°. And strengthened beam are also found that shear cracks appeared when loaded up to ultimate load.

V. COST ANALYSIS

1.9. General

In this chapter the detailed cost analysis was done for reinforced concrete and Retrofitting for R.C.C. member by using different glass Fibers.

Table 4.1: Comparison of load- deflection for strengthened beams

Load (KN)	**Control beam**	**Both Side Side**			**Bottom Side**			**U-Shape**		
		Single Mat	**Double Mat**	**Woven Roving**	**Single Mat**	**Double Mat**	**Woven Roving**	**Single Mat**	**Double Mat**	**Woven Roving**
0	0	0	0	0	0	0	0	0	0	0
50	0.360	0.0925	0.09	0.0725	0.066	0.064	0.059	0.039	0.035	0.026
100	1.250	1.35	1.025	0.625	0.978	0.742	0.391	0.575	0.568	0.223
150	3.842	3.125	3.015	2.425	2.264	2.185	1.035	1.390	1.388	0.866
200							2.425	2.201	2.200	1.556
250										2.249

Table No.5.1: Cost Analysis for different glass fibers wrap

Sr. no	Material	Single Mat			Double Mat			Woven Roving		
		Both Side wrap	Bottom wrap	U-Shape wrap	Both Side wrap	Bottom wrap	U-Shape wrap	Both Side wrap	Bottom wrap	U-Shape wrap
1	Material	34.20	12.80	47.02	68.20	25.60	94.04	106.6	27.2	99.82
2	Resin	130.43	48.80	179.34	260.86	97.60	358.68	260.86	97.6	358.68
Total		164.63	61.60	226.36	329.06	123.20	452.72	367.46	124.8	457.7
Labour rate		120.00	45.00	165.00	240.00	90.00	330.00	240	90	330
Grand Total		**284.63**	**106.60**	**391.36**	**569.06**	**231.20**	**782.72**	**607.4**	**214.80**	**787.7**

VI. DISCUSSIONS ON EXPERIMENTAL RESULTS

1.10. General

In this chapter, discussion is made on the effect of strengthening on the reinforced concrete beams by using different glass fiber with that of control beams, such as deflection and load carrying capacity.

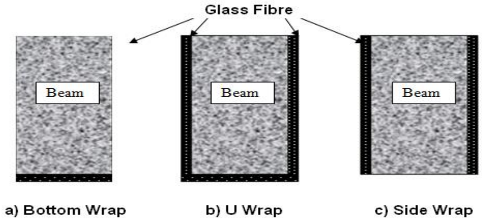
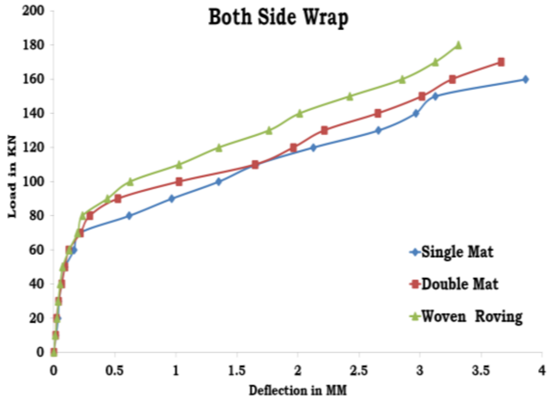


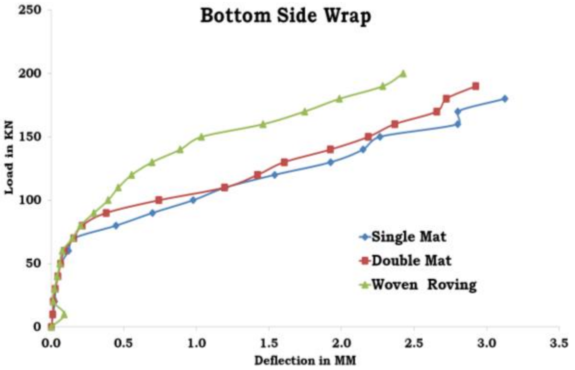
Fig. 6.1: Externally bonded FRP strengthening configurations

1.11. ith Respect To Load And Deflection



It may be observed from Fig.6.1 that the deflection of beams when bonded with GFRP both side wrap is lesser with that of control beams (SET I).

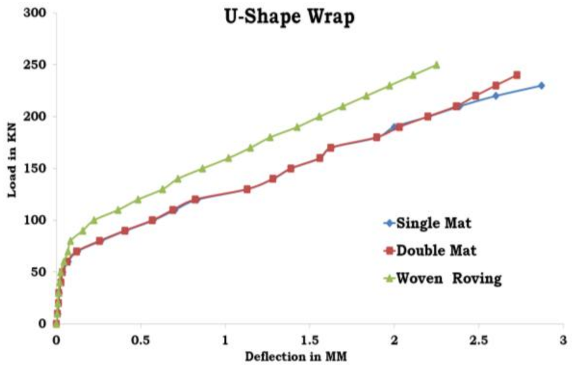
- Deflection of beam for both side GFRP wrap.
  1. The beam with both side single mat wrap is having the more deflection than that of double mat wrap and woven roving wrap.
  2. The beam with both side double mat wrap is having the minimum deflection than that of single mat wrap.
  3. Similarly, the beam with both side woven roving wrap is having the minimum deflection than that of single mat wrap and double mat wrap.
- Load on beam for both side GFRP wrap.
  1. The beam with both side single mat wrap can carry the more load 6.66% than that of control beam. G
  2. The beam with both side double mat wrap can carry the more load 13.33% than that of control beam.
  3. The beam with both side woven roving wrap can carry the more load 20% than that of control beam.



Graph6.2: Load Vs deflection for strengthened beams of Bottom side wrap

It may be observed from Fig.6.2 that the deflection of beams when bonded with GFRP bottom side wrap is lesser with that of control beams (SET I).

- Deflection of beam for bottom side GFRP wrap.
  1. The beam with bottom side single mat wrap is having the more deflection than that of double mat wrap and woven roving wrap.
  2. The beam with bottom side double mat wrap is having the minimum deflection than that of single mat wrap.
  3. Similarly, the beam with bottom side woven roving wrap is having the minimum deflection than that of single mat wrap and double mat wrap.
- Load on beam for both side GFRP wrap.
  1. The beam with bottom side single mat wrap can carry the more load 20% than that of control beam.
  2. The beam with bottom side double mat wrap can carry the more load 26.66% than that of control beam.
  3. The beam with bottom side woven roving wrap can carry the more load 33.33% than that of control beam.



Graph.6.3: Load Vs deflection for strengthened beams of U-Shape wrap

It may be observed from Fig.6.3 that the deflection of beams when bonded with GFRP U-Shape wrap is lesser with that of control beams (SET I).

- Deflection of beam for U-Shape GFRP wrap.

1. The beam with U-Shape single mat wrap is having the more deflection than that of double mat wrap and woven roving wrap.
2. The beam with U-Shape double mat wrap is having the minimum deflection than that of single mat wrap.
3. Similarly, the beam with U-Shape woven roving wrap is having the minimum deflection than that of single mat wrap and double mat wrap.

- Load on beam for both side GFRP wrap.

1. The beam with U-Shape single mat wrap can carry the more load 53.33% than that of control beam.
2. The beam with U-Shape double mat wrap can carry the more load 60% than that of control beam.
3. The beam with U-Shape woven roving wrap can carry the more load 66.66% than that of control beam.

1.12.

ITH RESPECT TO COST

Table No6.1 Cost of control & both side wrap beam.

Sr. no	Type of beam	Wrap	Cost in Rs.		
1	Control beam		539.70	539.70	539.70
2	Both side wrap	Single mat	284.63		
		Double mat		569.06	
		Woven roving			607.4
Total			**824.33**	**1108.76**	**1147.1**

Table No6.2 Cost of control & Bottom side wrap beam.

Sr. no	Type of beam	Wrap	Cost in Rs.		
1	Control beam		539.70	539.70	539.70
2	Bottom side wrap	Single mat	106.6		
		Double mat		231.2	
		Woven roving			214.80
Total			**646.3**	**770.9**	**754.5**

Table No.6.3 Cost of Control & U-Shape wrap beam

Sr. no	Type of beam	Wrap	Cost in Rs.		
1	Control beam		539.70	539.70	539.70
2	U-Shape wrap	Single mat	391.36		
		Double mat		782.72	
		Woven roving			787.7
Total			**931.06**	**1322.42**	**1327.74**

W

VII. CONCLUSION

The maintenance, rehabilitation and upgrading of RC structural members, is perhaps one of the most crucial problems in civil engineering applications. Moreover, a large number of structures constructed in the past using the older design codes in different parts of the world are structurally deficient according to the new design codes. Since replacement of such deficient elements of structures incurs a huge amount of money and time, strengthening has become the acceptable way of improving their load carrying capacity and extending their service lives. The experimental work was carried by Hand layup method, for that GFRP sheet was used, like E-Class Glass continuous filament mat and Woven roving mat. The Unsaturated polyester resin with cobalt accelerator and Hardner was used for wrap.

The experimental study consists of casting of four sets of reinforced concrete (RC) beams of grade M30, Total 30 no. of RC beam are casted and cured for 28 days, as show in table no.7.1

Table No. 7.1: Set of beam

	Normal	Single mat	Double mat	Woven roving	Total NOs
Control beam	3	-	-	-	3
Both Side wrap	-	3	3	3	9
Bottom wrap	-	3	3	3	9
U-Shape wrap	-	3	3	3	9
Total No. of beam.					**30**

The cross-sectional dimensions of 150mm x 200mm and 1000mm length, provided 2-12mm Ø bottom reinforcement and 2-8mm Ø top with 6mm Ø vertical stirrups @ 160mm c/c. All the specimens are tested in Universal testing machine (UTM). The experimentally obtained values are then compared with the control beam

GFRP is provided to increase the strength and stiffness of existing concrete beams when bonded to the both side, bottom side and U-Shape by using single mat, double mat and woven roving wrap as compare to control beam, however the mode of failure associates with application of GFRP was more ductile and preceded by warning signs such as snapping sounds or peeling of the GFRP. Yet the results of this study show that GFRP can be used to increase the strength and stiffness of beams without causing catastrophic brittle failure associated with this strengthening technique. With reference to experimental result Strength and cost comparison are shown in table 7.2

Table No. 7.2: Strength and Cost Comparison

	Single Mat		Double Mat		Woven Ring	
	% Increase in Strength	Cost$^{\infty}$	% Increase in Strength	Cost$^{\infty}$	% Increase in Strength	Cost$^{\infty}$
Both Side Warp	6.66 %	284.63	13.33%	569.06	20.00 %	607.4
Bottom Side Warp	20 %	106.06	26.66 %	231.20	33.33 %	214.80
U Shape Warp	53.33 %	391.36	60 %	782.72	66.66 %	787.72

∞ *Additional Cost then Control Beam (539.70)*

With reference to above table; it is cleared that U-Shape wrap and bottom wrap was good for improving shear strength as well as for reducing deflection of RC member as compare to both side wrap. Even if initial cost of U-Shape wrap is more then also comparing to high strength results, The strength of U-Shape wrap beam was increased by 46% as compare to both side wrap beam.

Cost of woven roving wrap was more as compare to single mat and double mat wrap but load carrying capacity also increases as compare to single mat and double mat wrap. It was indicated that woven roving U-Shape wrap is more beneficial and preferable for Retrofitting. Retrofitting is always affordable to strengthen the structure than replacement. It avoids excess time required for replacement and reduces cost of material and labour.

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