STRENGTHENING OF RC BEAMS USING GLASSFIBRE REINFORCED POLYMER SHEETS AND COMPARISON OF U WRAP AND 90 DEGREE STRIP WRAP.

Mohammed Suneer, Er Rajeev V.S, Er Sajan jos

[1]*PG Student, Dept. of Civil Engineering, Universal Engineering College, Thrissur. Kerala.*
[2]*Assistant Professor, Dept. of Civil Engineering, Universal Engineering College, Thrissur. Kerala.*
[3]*Assistant Professor, Dept. of Civil Engineering, Universal Engineering College, Thrissur. Kerala*

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Abstract:

Strengthening of reinforced concrete beams with externally bonded fiber reinforced composites is a technique that has been developed in recent years. Here in the present study Glass Fiber reinforced polymer sheets are used for finding behavior of beams strengthened with composite materials. Eight beams are casted, two beams as control beams. Resin mortar with promoter, catalyst, and accelerator, is used as a binding materials in various patterns. After 24 hours of wrapping and 7 days air curing beams are tested .U wrapping, Bottom wrapping, 45 degree U wrapping, 90 degree U wrapping, Combination of Bottom wrapping with 90 degree u wrapping are tested in static three point loading frame set up. The test results were evaluated in terms of load deflection behavior, ultimate load carrying capacity, ultimate deflection, crack patterns and associated failure modes. The results obtained clearly demonstrate the effectiveness of strengthening of RC beams using Glass reinforced polymer sheets. The beams treated with Resin mortar with accelerator, catalyst and promoter improved the strength and load carrying capacity.

Keywords: **Glass Fiber reinforced Polymer (GFRP), Strengthening , Retrofitting Three Point Loading Frame, Catalyst, Promoter, and Accelerator, Load Carrying Capacity, Wrapping.**

1. INTRODUCTION

Reinforced Concrete (RC) structures have been one of the major structural materials for over a century and are still the most popular material for public structures all over the world.Reinforced concrete beams are structural elements designed to carry transverse external loads.These loads causes bending moment, shear forces and torsion across their length in some cases. Concrete is strong in compression and very weak in tension.Thus, steel reinforcement used to take up tensile stresses in RC beams. In recent years, the field of concrete structure strengthening has become a hot point. As a result, the related strengthening techniques of concrete structure have been an important research field in structural engineering. The use of composites for strengthening and repairing RC structures has gained importance in civil engineering. Strengthening of reinforced concrete structures with externally bonded fiber reinforced polymer (FRP) composites is a newly developed technique in recent years. Generally, FRP strengthened RC beams consists of four materials ie concrete, steel bars, adhesives, and FRP reinforcement. Benefits of FRP composites include light weight, high strength and high modulus, durability and impact resistance. FRP's structural properties are useful in absorbing seismic or blast energy, and this property lets the material to act as a polymer damper at flooring area and connection zone. These are successfully implemented to enhance the performance of structural elements in flexure, axial, shear, and torsion. The commonly used FRP has some drawbacks like debonding of FRP from the concrete, poor behaviour of epoxy at high temperature, inability to apply on wet surface, relatively high cost, etc. and these can be solved by using Glass, fibers, Basalt fiber, Nylons etc.

2. MATERIALS USED

2.1 CONCRETE

Concrete is a construction material of Portland cement and water combined with sand, gravel, crushed stone, or other inert material such as expanded slag or vermiculite. The cement and water form a paste which hardens by chemical reaction into a strong, stone- like mass. The quality of the paste formed by the cement and water largely determines the character of the concrete. Proportioning of the ingredients of concrete is referred to as designing the mixture, and for most structural work the concrete is designed Compressive strengths of 15 to 35 MPa. Pozzolona Portland cement will be used. Ordinary clean portable water free from suspended particles and chemicals will be used for both mixing and curing of concrete.

2.2 REINFORCEMENT

The longitudinal reinforcements used were high- yield strength deformed bars of 10mm diameter and 10 mm diameter were used as hanger bars. . The stirrups were made from mild steel bars with 8mm diameter.

2.3 GLASS FIBRE REINFORCED SHEETS

Glass fiber reinforced polymer (GFRP) is a composite construction material resulting from the combination of unsaturated polyester based resin used as a binder with glass fiber. The fibers may be randomly arranged, flattened into a sheet (called a chopped strand mat). These are fibers commonly used in the naval and industrial fields to produce composites of medium- high performance.Their peculiar characteristic is high strength. Glass is made up of silicon (SiO_2) with tetrahedral structure (SiO_4).

Fig 1.1: Glass Fiber Sheet

Table 1.1: Properties of Glass fiber reinforced polymer sheets.

Material characteristics	Glass fiber reinforced polymer sheets
Density (g/cc)	2.60
Tensile Strength (MPa)	2050
Elastic Modulus	85

The major advantages of glass fibers are:

- Cheaper and more flexible than carbon fiber
- Stronger than many metals by weight
- Non-magnetic and non-conductive
- Highly flexible and can be moulded into complex shapes
- Chemically inert under many circumstances
- Inherent strength
- Weather-resistant finish
- Thermal resistant

2.2 MORTAR RESIN

Epoxy Mortar is a polymer based bonding paste that comprises materials such as epoxy resins (Vinyl Ester), hardener Cobalt Ocatate), catalyst (MEKP- Ketone Peroxide) and Promoter.

It is used to bind the glass fiber sheets with concrete specimens in the form of coatings for resisting debonding failures. The compressive strength of resin mortar is lower than ordinary Portland cement. The toughness of epoxy resin is better than ordinary Portland cement.

Fig1.2.1: Resin mortar with catalyst, hardener and catalyst

3. RETROFITTING OF BEAMS

Before bonding the composite fabric onto the concrete surface, the required region of concrete surface was made rough using a coarse sand paper texture and cleaned with an air blower to remove all dirt and debris. Then apply cement mortar on cracked surfaces to fill cracks formed due to axial loading Once the surface was prepared to the required standard, the epoxy resin was mixed. Mixing was carried out in a plastic container and was continued until the mixture was in uniform colour. When this was completed and the fabrics had been cut to size, the epoxy resin was applied to the concrete surface. The composite fabric was then placed on top of epoxy resin coating and the resin was squeezed through the roving of the fabric. This operation was carried out at room temperature. Concrete beams strengthened with glass fiber fabric were cured for 48 hours at room temperature before testing.

Fig 3.1: Application and fixing of glass fibre sheet and resin mortar

3.2: U wrapping using glass fiber sheets

Fig 3.3: 90 degree wrapping using glass fiber sheets

Fig 3.4: Combination of 45degree and 90 degree strip wrapping using glass fiber sheets (white cement applied)

4. TWO POINT LOADING

In two point loading the load is transmitted through a load cell and spherical seating on to a spreader beam. This beam bears on rollers seated on steel plates bedded on the test member with mortar, high- strength plaster or some similar spreader plates. The loading frame must be capable of carrying the expected test loads without significant distortion. Ease of access to the middle third for crack observations, deflection readings and possibly load corresponding to each deflection is noted. Crack patterns are marked with different colour pens when formed at failure,

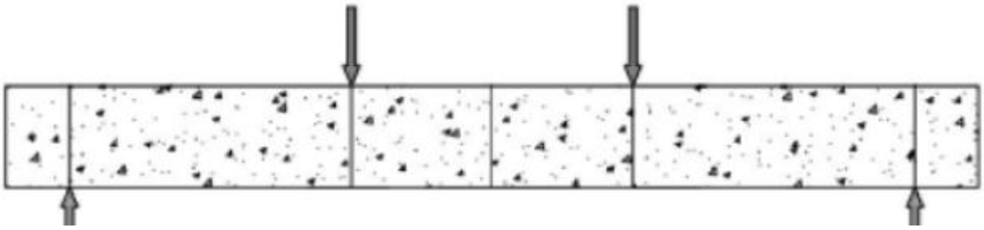


Fig 4.1: Two point loading of beams

Fig 4.2: Shear force diagram

Fig 4.3: Bending moment diagram

Fig 4.4: Experimental set up for beams

4. PROJECT PROCEDURES

4.1 Cube compressive strength

Casting of concrete specimens is done as per Indian Standards. M20 mix is chosen and done mix design. Mix ratio obtained is 0.47: 1: 1.67: 2.79. Compressive strength of concrete is determined by making cubes of size 150 mm x 150 mm. Cubes are made by finding out the required amount of quantities of materials using mix proportion. Mixing of concrete is carried out manually. Compressive strength is the capacity of a material or the ability of a structure to withstand load tending to reduce size. Totally 15 cubes were casted for determination of compressive strength. After 24 hours the mould were demoulded and subjected to water curing. Before testing the cubes were dried for 2 hours. All the cubes were tested in saturated conditions after wiping out surface moisture. The load was applied without shock and increased continuously until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen was then recorded; three cubes each were tested at the age 7 days and 28 days of curing for concrete compression testing.

Fig 4.1.1: Unmoulded specimen for testing

Fig 4.1.2: Compression test for cube specimen

Table 4.1.1: Compression test values

Cube No.	C/S (mm2)	7 days Strength (N/mm2)	28 days Strength (N/mm2)
Cube 1	150 x 150	14.66	28.88
Cube 2	150 x 150	15.11	28.88
Cube 3	150 x 150	15.12	30.22
Average		14.96	29.47

4.2 TESTING OF CYLLINDERS

Casting of concrete specimens is done as per Indian Standards. M20 mix is chosen and done mix design. Mix ratio obtained is 0.47: 1: 1.34: 2.29. Compressive strength of cylinders of size 150 mm x 300 mm x 150 mm is determined. Cylinders are made by finding out the required amount of quantities of materials using mix proportion. Mixing of concrete is carried out manually.

First the coarse aggregate and fine aggregate are mixed. After that the cement is poured into the mixer. Required amount of water is added. And the resulting concrete with uniform appearance is transferred to moulds. In assembling the mould for use, the joints between the sections of mould is thinly coated with mould oil and a similar coating of mould oil is applied between the contact surfaces of the bottom of the mould and the base plate in order to ensure that no water escapes during the filling. The interior surfaces of the assembled mould are thinly coated with mould oil to prevent adhesion of the concrete. After 24 hours of air curing the specimens are transferred to the curing tank.

Fig 4.2.1: Testing of cylinder specimens

Table 4.2.1: Tensile strength of specimens

Cube No.	C/S (mm2)	28 Day Strength (N/mm2)
1	150 x 300	2.83
2	150 x 300	2.97
Average		2.9

4.3 SPECIMEN PREPERATION AND TESTING

Form work making use of plywood was prepared for the beam of size 1700mm x150 mm x 200mm size. A total of 8 beams were cast where in 2 were controlled specimens and 2 were subjected to U-wrapping and other 2 specimens were subjected to 90 degree strip wrapping and 2 were subjected to 45 degree strip wrapping. Each of the specimens were singly reinforced and under reinforced section. Without delay after the beam cast, the beams were covered with plastic sheet to minimize the evaporation of water from the surface of the beam specimen. After 24hours, the sides of the formwork were removed and the beams were lowered into a curing tank for 28 days, after which the beams were left alone until the time of test.

Before testing, beams were whitewashed and then the surface was rubbed with sand paper and tested in two points loading with a maximum capacity of 30 tons The beam was placed over the two steel rollers bearings leaving75 mm from the both sides of beam. Rest of the part was equally divided in to three equal parts. Load was applied by loading cell of 1000 kN. Two dial gauges were used for recording deflection. One dial gauge was placed at center and other was placed under the one of the point load to note the deflection. Beams were tested before and after retrofitting. First of all control beam was tested with full load to get the maximum collapse load, then after other beams were tested with load of 75% of collapse load.

Fig 4.3.1: Testing of beams before retrofitting and initial cracks are marked

Fig 4.3.2: Cracked specimen marked

Fig 4.3.3: Testing of beams after retrofitting with wrapped glass fiber sheets

Fig 4.3.3: Cracked beams after retrofitting

4.4 WRAPPING PATTERNS

Totally we have six beams from which 2 for U wrapping, 2 for 45 degree strip wrapping and 2 for 90 degree strip wrapping. Here U wrapping and 90 degree strip wrapping are considered for the study.90 degree and U wrapping are the two patterns of wrapping beams using glass fiber sheets. For the 90 degree strip, wrapping the glass fiber sheet is cut in to strips of 5mm pieces and pasted on the surface of effective length of collapsed beam in 5mm of spacing to save the cost of materials. It requires only 0.36 square meter of glass fiber to wrap one beam specimen.

Strips are pasted on the beam using resin mortar by flat blade in 90 degree U shaped excluding top surface and keep wrapped beams in room temperature for 48 hours and tested. For U wrapping glass fiber sheet is cut in to shape of U and is pasted on three sides of effective length of collapsed beam using resin mortar as bonding agent. For U wrapped beam it requires one square meter of glass fiber to wrap the beam specimen After 48 hours keeping specimens at room temperature, two specimens of U wrapped and two specimens of 90 degree strip wrapped beams are tested in two point loading frame and compared the results by taking best of two readings.

Fig 4.4.1: 90 degree strip wrapped collapsed beam for retrofitting

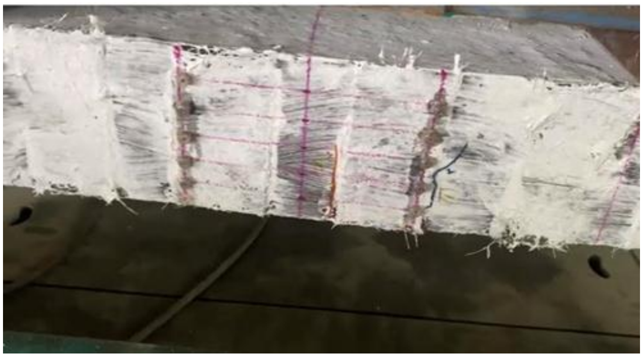


Fig 4.4.2: Cracked patterns on 90 degre strip wrapped collapsed beam after loading

Fig 4.4.3: U wrapped collapsed beam for retrofitting

Fig 4.4.4: Cracked patterns on U wrapped collapsed beam after loading

4.5 GRAPHICAL RESULTS

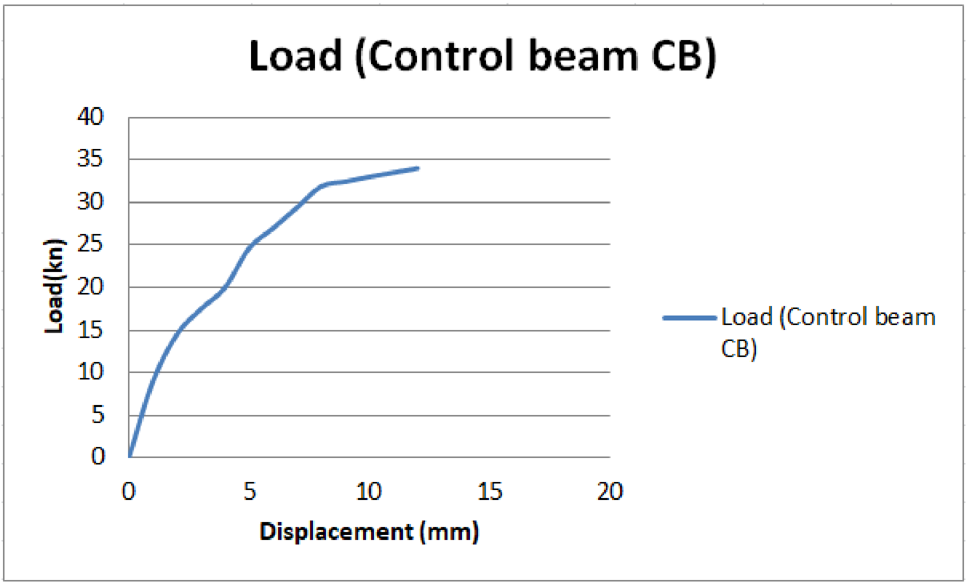


Fig 4.5.1: Load v/s dispalcement graph of control beam (CB)

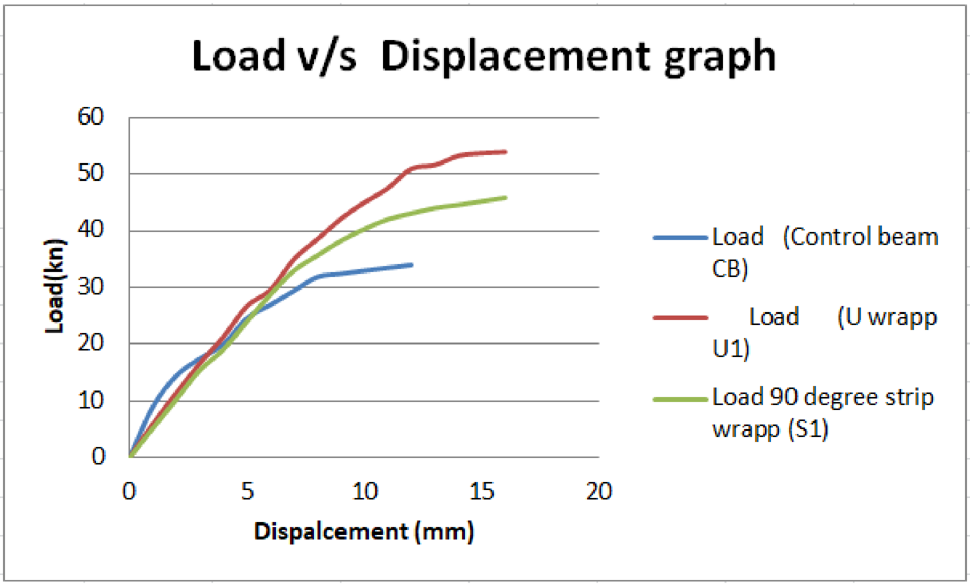


Fig 4.5.2: Load v/s deflection graph of U wrap beam (U1) v/s 90 degree strip wrap beam (S1)

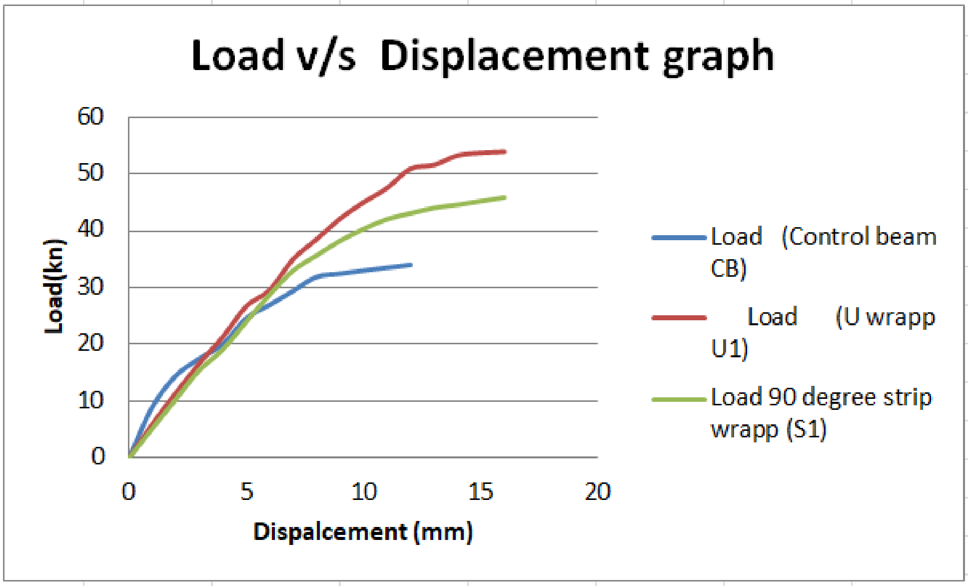


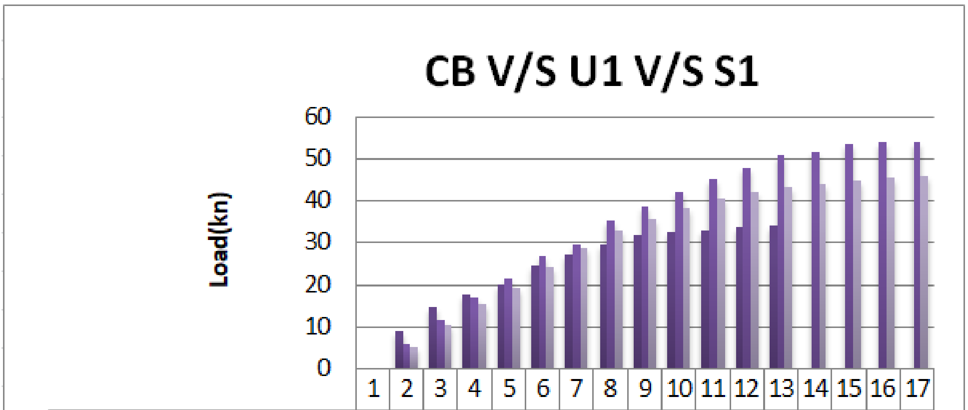
Fig 4.5.3: Load v/s displacement graph of Control beam CB v/s U wrap beam (U1) v/s 90 degree strip wrap beam (S1)

4.6: COMPARITIVE STUDY

Here we taken three beams for the comparative study.1.non retrofitted control beam (CB) 2.retrofitted beam by U wrap (U1) 3.retrofitted beam by 90 degree wrap (S1).Control beam is the mother beam which is fully collapsed with a ultimate load capacity of 34 kN and other two beams are loaded by 75 percentage of collapsed Here we taken best one of two readings on each wrapping styles. After retrofitting one of partially loaded beam specimen by U wrap using glass fiber on effective length excluding top layer we get maximum load carrying capacity of 54 kN and 90 degree strip wrapped beam by 46 kN.

Table 4.6.1: Load carrying capacity of CB, U1&S1

SPECIMEN	LOAD CARRYING CAPACITY(kN)
Control beam (CB)	34
Beam 1 (U1)	54
Beam 2 (S1)	46



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Load (Control beam CB)	0	9	15	18	20	25	27	29	32	32	33	34	34				
Load (U wrapp U1)	0	6	11	17	21	27	30	35	39	42	45	48	51	52	53	54	54
Load 90 degree strip wrapp (S1)	0	5.2	10	15	19	24	29	33	36	38	40	42	43	44	45	45	46

Fig 4.6.1: Bar graph of CB, U1& S1

5. CONCLUSION

- A total of six beams were cast out of which two were controlled beams and two were retrofitted or wrapped by U wrap and the other two by 90 degree strip and taken best value of two readings After applying 75% of the Ultimate Load No horizontal cracks were observed at the level of the reinforcement, which indicated that there were no occurrences of bond failure. Other important conclusions are as follows:

- The load carrying capacity obtained two patterns are good and can be considered as good solution for strengthening of RC collapsed beams.

- There is considerably increase in load carrying capacity of U wrapped beam by 20% compared and 90 degree wrapped beam by 12 % compared to control beam.

- The load carrying capacity of beams wrapped by U wrap is larger (54kN) as compared to the 90 degree wrapped beam for strengthening or retrofitting.As economical point of view each U wrapped beam covers an area of 0.36 meter glass fiber material is very large as compared with 90 degree U wrapped beam.

- So it is experimentally proved that , if U wrapped beam have load carrying capacity of 54 kN by consuming one square meter glass fiber and 90 degree wrapped beam of 46 kN by consuming very less area of material ie 0.36, 90 degree wrap pattern is good and economical for strengthening of collapsed beam.

- Control beam loses initial stiffness while collapsed, but we wrapped or retrofitted collapsed beams it gains some stiffness and dhows ductility sufficient behaviour as compared to control beam

ACKNOWLEDGEMENTS

The authors would like to acknowledge God Almighty for His eternal grace and guidance as well Er Nithin Mohan., PHD Scholar,IIT Bombay and Mrs AnimaP, Associate Professor, Universal Engineering College, Thrissur.Kerala, for all amazing guidances and support.

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