

## **COMPARATIVE STUDY OF PARTIALLY WRAPPED RC BEAMS AT DIFFERENT SPACINGS**

Jahnavi. Y<sup>1</sup>, Satya Durga. K<sup>1</sup>, Ajay Shankar<sup>1</sup>, Teja<sup>1</sup>, Pavan Sai Krishna<sup>1</sup>, and Prajna Bharati<sup>2</sup>

<sup>1</sup> UG students, Department of Civil Engineering, Aditya Engineering College (A), Surampalem, India

<sup>2</sup> Assistant professor, Department of Civil Engineering, Aditya Engineering College (A), Surampalem, India

### **Abstract**

In the present study the strength behavior of strengthening includes FRP wrapping, concrete jacketing etc. Using the RC beam wrapped partially with the FRP sheets is studied. For this an RC beams of size 100mm × 100mm × 500mm is reinforced with 4 # 8mm diameter steel bars are casted. The RC beam is wrapped with strips of GFRP sheets at different spacings of constant FRP sheet material area. Strength properties of partially wrapped beams are compared with the control beams (CB) without GFRP wrapping. Comparative study is carried out between the partially wrapped GFRP beams with different spacings. An increase in load carrying capacity is observed in partially wrapped beams comparison with controlled i.e., 9% increase in double wrapped beams and 16% increase in triple wrapped beams after 7 days test and 3.2% increase in double wrapped beams and 4.8% increase in triple wrapped beams after 28% test.

**Keywords:** GFRP sheets, concrete jacketing, FRP wrapping, Concrete etc.

### **Introduction:**

The majority of structural strengthening involves improving the ability of the structural element to safely resist one or more of the following internal forces caused by loading: flexure, shear, axial, and torsion. Strengthening is accomplished by either reducing the magnitude of these forces or by enhancing the member's resistance to them. Typical strengthening techniques such as section enlargement, externally bonded reinforcement, post-tensioning, and supplemental supports may be used to achieve improved strength and serviceability. The use of fiber reinforced polymers (FRPs) for the rehabilitation of existing concrete structures has grown very rapidly over the last few years, 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 glass fiber-reinforced polymers (GFRP) can be used to enhance the flexural, shear and torsional capacity of RC beams. Due to the flexible nature and ease of handling and application, 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.

**Methodology:**

FRP is a composite material generally consisting of high strength carbon, aramid, or glass fibers in a polymeric matrix (e.g., thermosetting resin) where the fibers are the main load carrying element. 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.

**Experimental Investigation:**

The purpose of this research is to investigate the flexural behaviour of reinforced concrete beams strengthened with varying configuration and layers of GFRP sheets. More particularly, the effect of the number of GFRP layers and its orientation on the strength of beams is investigated. Three sets of beams were fabricated and tested up to failure. In SET I six beams weak in flexure were casted, which were controlled beams and were tested for 7 days and 28 days after curing. In SET II six beams weak in flexure were casted, in which were wrapped in two layers and after curing tested for 7 days compressive strength and 28 days compressive strength. In SET III six beams weak in flexure were casted, in which were wrapped in three layers and after curing were tested for 7 days compressive strength and 28 days compressive strength.

**Objective of the Study:**

- By observing the literature available, studies are limited to full wrapping of FRP sheet around the columns. Also, studies using FRP strips are very meager.
- To study the flexural and shear behavior of reinforced concrete beam
- To calculate the effectiveness of the external Glass Fiber-Reinforced Polymer (GFRP) wrapping technique in Strengthening of Reinforced Concrete (RC) Beam.

- To study the ultimate load carrying capacity of the specimens in strengthening by Glass Fiber-Reinforced Polymer (GFRP) wrapping technique.
- To Measure the efficiency of the Glass Fiber-Reinforced Polymer (GFRP) fabrics in terms of utilization of the strength and deformation capacity of the FRP material.
- Evaluation of the results obtained from the Un-strengthen RC beam and Strengthen RC beams with different combinations of wrapped glass fiber reinforced polymer (GFRP).

## Materials:

- Cement – Ordinary Portland cement (OPC) of grade -53.
- Fine aggregate – Sand obtained from Godavari riverbed of size 4.75mm.
- Coarse aggregate - Crushed angular stones obtained on quarrying from local site.
- Reinforcement - provided using rebars, main bars of size 460mm @8mm diameter and bent up bars of size 280mm @6mm diameter.
- FRP sheets – Glass Fiber Reinforced Polymer Sheets of thickness 0.011mm brought from Vrushka Composites Guntur.
- Epoxy Resin Gum – Nitobond EP Based Epoxy Resin Gum brought from Maruthi Chemicals and Interior Products, Tamil Nadu.



Fig1: OPC grade 53 cement



Fig 2: 20mm size fine aggregate



Fig 3: 20mm size coarse aggregate



Fig 4: reinforcement bar



Fig 5: fiber matrix

**Fiber Properties:**

Types of fibres used in reinforced polymer composites:

- Glass fibres
- Carbon fibres
- Aramid fibres

Material	Density (g/cm <sup>3</sup> )	Tensile Modulus (E) (GPa)	Tensile Strength ( $\sigma$ ) (GPa)	Specific Modulus (E/ $\sigma$ )	Specific Strength	Relative Cost
E-glass	2.54	70	3.45	27	1.35	Low
S-glass	2.50	86	4.50	34.5	1.8	Moderate
Graphite, high modulus	1.9	400	1.8	200	0.9	High
Graphite, high strength	1.7	240	2.6	140	1.5	High
Boron	2.6	400	3.5	155	1.3	High
Kevlar 29	1.45	80	2.8	55.5	1.9	Moderate
Kevlar 49	1.45	130	2.8	89.5	1.9	Moderate

Table 1 Properties of different fibres





Discontinuous fibers.



Discontinuous fibers mat.

Fig 6: Discontinuous Glass Fibres

**Fiber Sheet:**

Fibre sheet used in this experimental investigation was E-Glass Bi-directional woven roving mat it was susceptible to atmospheric agents. It was chemically resistive, anti-corrosive has high strength to weight ratio, high durability, provides good bond strength. Below fig 7 shows the picture of bi- axially rowen mat brought from Vrushka composites Guntur and fig 8 shows 10x10cm piece of thickness 0.11mm is cut out from biaxially rowen mat.



Fig 7: biaxially rowen glass fiber mat

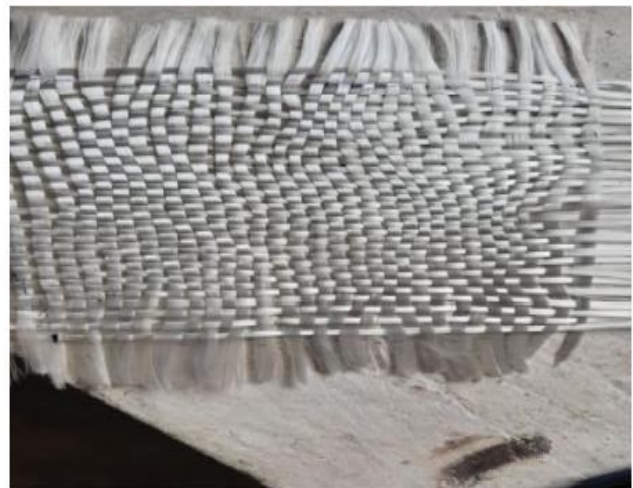


Fig 8:10\*10cm Glass fiber sheet obtained from vrushka composites

**Experimental Investigation:**

The purpose of this research is to investigate the flexural behaviour of reinforced concrete beams strengthened with varying configuration and layers of GFRP sheets. More particularly, the effect of the number of GFRP layers and its orientation on the strength of beams is investigated. Three sets of beams were fabricated and tested up to failure. In SET I six beams weak in flexure were casted, which were controlled beams and were tested for 7 days and 28 days after curing. In SET II six beams weak in flexure were casted, which were strengthened using glass fibre sheets and tested for 7days compressive strength after curing. In SET III six beams weak in flexure were casted, which were

strengthened by using glass fibre sheets and were tested for 28 days compressive strength after curing. The strengthening of the beams is done with varying configuration and layers of GFRP sheets. Experimental data on load, deflection, and failure modes of each of the beams were obtained. The change in load carrying capacity and failure mode of the beams are investigated as the amount and configuration of GFRP sheets are altered.

**Casting of Beams:**

Three sets of beams were casted for this experimental test program. In SET I six beams (F1, F2, F3, F4, F5, F6) weak in flexure were casted using same grade of concrete and reinforcement detailing. In SET II six beams (Dw1, Dw2, Dw3, Dw4, Dw5, Dw6) weak in flexure were casted using same grade of concrete and reinforcement detailing and were strengthen with glass fiber sheet. In SET III six beams (Tw1, Tw2, Tw3, Tw4, Tw5, Tw6) weak in flexure were casted using same grade of concrete and reinforcement detailing and were strengthened with glass fiber sheet. The dimensions of all the specimens are identical. The cross-sectional dimensions of three sets of beams are 100 mm by 100 mm by 500 mm. The purpose of this research is to investigate the flexural behaviour of reinforced concrete beams strengthened with varying configuration and layers of GFRP sheets.



fig 9: preparation of beams for casting

**Form Work:**

Fresh concrete, being plastic requires form work to mould it to the required shape and also to hold it till it sets. The form work has, therefore, got to be suitably designed. It should be strong enough to take the dead load and live load, during construction and it must be rigid enough so that any bulging, twisting, or sagging due to the load is minimized. Wooden beams, mild steel sheets, wood, and several other materials can also be used. Formwork should be capable of supporting safely all vertical and lateral loads that might be applied to it until such loads can be supported by the ground, the concrete structure, or other construction with adequate strength and stability.



Fig 11: mixing of concrete

All specimens were compacted by using vibrator for good compaction of concrete. Sufficient care was taken to avoid displacement of the reinforcement cage inside the form work. Finally, the surface of the concrete was leveled and finished and smoothed by metal trowel and wooden float. The concrete is now kept for curing.



Fig 12 : casted beam in mold after 24 hardening

**UTM Test:**

Before testing the member was checked dimensionally, and a detailed visual inspection made with all information carefully recorded. After setting the computer and load gauge, the load was increased incrementally up to the calculated working load, with loads and deflections recorded at each stage. Loads will then normally be increased again in similar increments up to failure, with deflection gauges replaced by a suitably mounted scale as failure approaches.



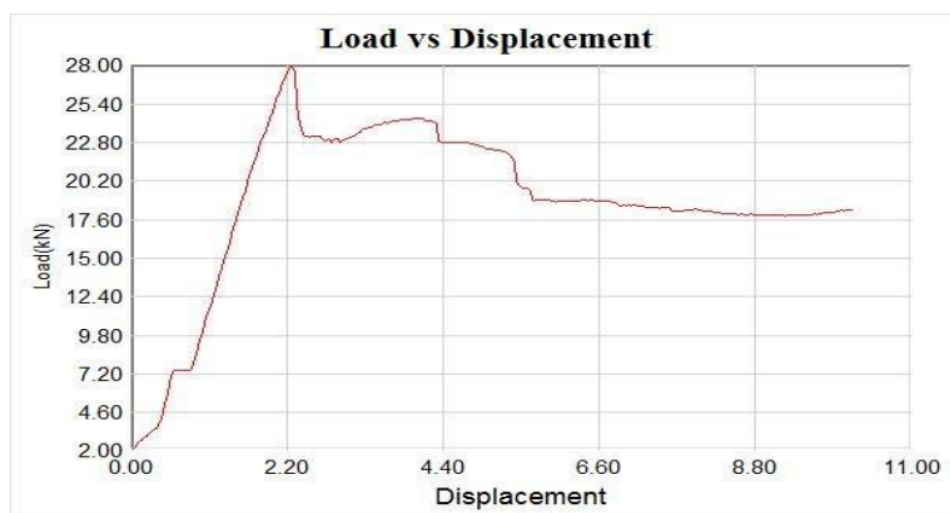


fig 13: controlled beams placed in UTM for testing

**Test Results: 7 days**

S. No	Controlled Beam F1		Controlled Beam F2		Controlled Beam F3	
	Load (KN)	Displacement(mm)	Load (KN)	Displacement(mm)	Load (KN)	Displacement(mm)
1	4	1.2	7.20	0.7	8.3	0.7
2	6	1.4	19.33	1.4	18.23	1.4
3	7.5	1.7	27.2	2.1	26.2	2.1
4	21.97	2	21.07	2.8	27.98	2.8
5	19	3.6	18.21	3.5	25.2	3.5
6	18.2	4.5	17.6	4.2	24.3	4.2
7	17.8	7.2	16.8	4.9	23.9	4.9
8	15.3	9.7	15.87	5.6	23.2	5.6
9	13.8	10.8	14.50	6.3	22.5	6.3
10	13	12	13.20	7	21.9	7

Table 2 load vs displacement values for controlled beams F1, F2, F3 after 7 days test.



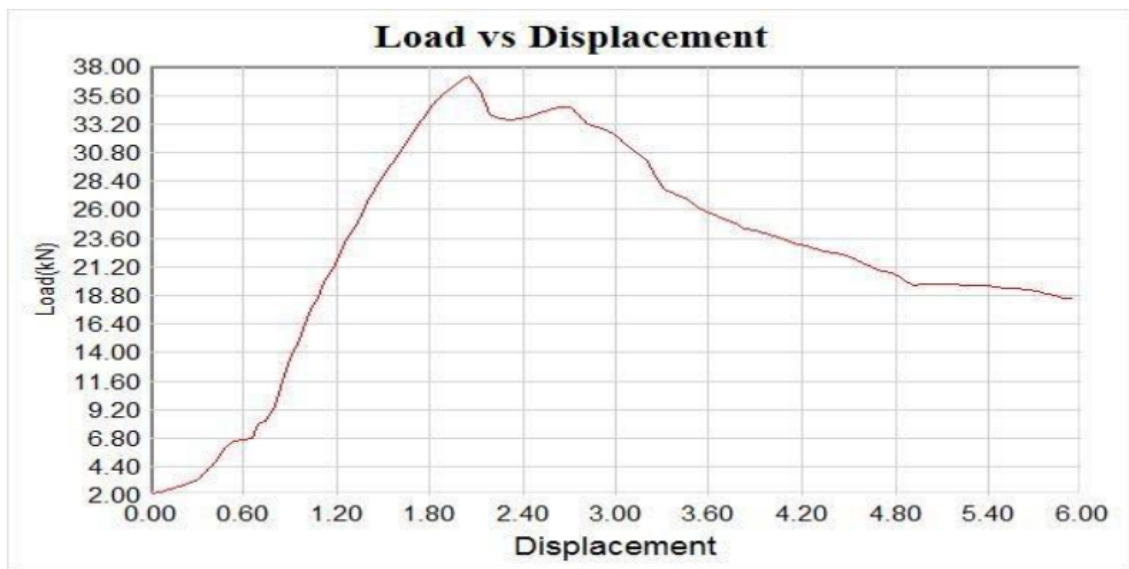
Graph 1: load vs displacement graph for controlled beam F1



**Test Results: 28 days**

S. No	Controlled Beam F4		Controlled Beam 2 F5		Controlled Beam 3 F6	
	Load (KN)	Displacement(mm)	Load (KN)	Displacement(mm)	Load (KN)	Displacement(mm)
1	5.2	0.4	5.1	0.4	9.1	0.4
2	6.7	0.57	7.2	0.57	17.2	0.57
3	6.8	0.6	9.1	0.6	19.9	0.6
4	21.2	1.2	19.2	1.2	24.11	1.2
5	37.18	1.8	27.98	1.8	23.2	1.8
6	33.2	2	26.2	2	21.9	2
7	31.4	2.4	25.9	2.4	20.7	2.4
8	26	3	24.3	3	19.2	3
9	23.4	3.6	23.2	3.6	18.3	3.6
10	21.2	4.2	22.9	4.2	17.7	4.2

Table 3 load vs displacement values for controlled beams F4, F5, F6 after 28 days test.



Graph 2: load vs displacement graph for controlled beam F4

**Conclusion:**

The percentage increase in load carrying capacity of FRP strengthened beams compared with control beams (CB): for 7 days 10% for doubly wrapped beams, 12% for triple wrapped beams for 28 days 6% for doubly wrapped and 7% for triple wrapped.

- The bonding between GFRP sheet and the concrete is intact up to the failure of the beam which clearly indicates the composition action due to GFRP sheets.
- Restoring or upgrading the strength of beam using GFRP sheets can result in increased strength and stiffness with no visible shear cracks.
- Restoring the strength of the beams using GFRP sheets is highly effective.

- Initial cracks appear at higher loads when beam is strengthened up to neutral axis using GFRP sheets i.e three layer wrapping of beams.
- As the strength of beam increases the load carrying capacity of the beam also increases leading to delay in crack production time.
- Triple layer and double layer wrapping beams have more flexural strength which is due to increase in bonding of concrete obtained on wrapping with GFRP sheets.
- Beams wrapped up to neutral axis (three-layer wrapping) pose more load carrying capacity as most of the strength of the beam is available at neutral axis

**References:**

1. MZ Naser, Rami Antoun Hawileh, Jamal Abdalla, Modelling strategies of finite element simulation of reinforced concrete beams strengthened with FRP, *journal of composite science* 5(1),19,2021.
2. Bouziadi, F.; Boulekbache, B.; Haddi, A.; Hamrat, M.; Djelal, C. Finite element modeling of creep behaviour of FRP-externally strengthened reinforced concrete beams. *Eng. Struct.* 2020, 204, 109908.
3. Godat, A.; Challal, O.; Obaidat, Y. Non-linear finite-element investigation of the parameters affecting externally bonded FRP flexural-strengthened RC beams. *Results Eng.* 2020, 8, 100168.
4. Nie, X.F.; Zhang, S.S.; Chen, G.M.; Yu, T. Strengthening of RC beams with rectangular web openings using externally bonded FRP: Numerical simulation. *Compos. Struct.* 2020, 248, 112552.
5. Gribniak, V.; Misiūnaitė, I.; Rimkus, A.; Sokolov, A.; Šapalas, A. Deformations of FRP–Concrete Composite Beam: Experiment and Numerical Analysis. *Appl. Sci.* 2019, 9, 5164.
6. Naser, M.Z. Properties and material models for modern construction materials at elevated temperatures. *Computer. Mater. Sci.* 2019, 160, 16–29.
7. Hawileh, R.A.; Kodur, V.K.R. Performance of reinforced concrete slabs under hydrocarbon fire exposure. *Tunn. Undergr. Sp. Technol.* 2018, 77, 177–187.
8. Džolev, I.M.; Cvetkovska, M.J.; Ladinović, D.; Radonjanin, V.S. Numerical analysis on the behaviour of reinforced concrete frame structures in fire. *Computer. Concr.* 2018, 21, 637–647.
9. Athira M. A., Meera C. M., Sreepriya Mohan- “Experimental Study on RC Columns Wrapped with Hybrid Frp Sheets” (2016).
10. Sallam, Y. S. and Ahmad, S., “Effect of Concrete Strength Class on Performance of CFRP-Confined Concrete under Compression,” *Journal of Testing and Evaluation*, Vol. 44, No. 1, (2016).