Behaviour of R.C Beam and Glass Fiber Reinforced Polymer Composite Beam for Shear Strength

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Abstract—*Fiber- reinforced polymer (FRP) application is a very effective way to repair strengthens 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 investigations on the shear behaviour of RC beams strengthened using continuous glass fiber reinforced polymer (GFRP) sheets are carried out. Externally reinforced concrete beams with epoxy-bonded GFRP sheets were tested to failure using a symmetrical two point loading system. The strengthening of the beams is done with different amount and configuration of GFRP sheets. Experimental data on load, deflection and failure modes of each of the beams were obtained. The detail procedure and applications 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 investigated*

Keywords—strengthening, glass fiber composites, epoxy resin, reinforced concrete beam, shear force.

I. INTRODUCTION

The use of fiber reinforced polymer (FRP) materials in civil infrastructure for the repair and strengthening of reinforced concrete structures and also for new constructions has become common practice. The most efficient technique for improving the shear strength of deteriorated RC members is to externally bond fiber- reinforced polymer (FRP) plates or sheets. External plate bonding is a method of strengthening which involves adhering additional reinforcement to the external faces of a structural member. The success of this technique relies heavily on the physical properties of the material used and on the quality of the adhesive, generally an epoxy resin, which is used to transfer the stresses between the flexural element and the attached reinforcement. The major constituents of FRP are the fiber and the resin. The mechanical properties of FRP are controlled by the type of fiber and durability characteristics are affected by the type of resin. FRP can be applied for strengthening a variety of structural members like beams, columns, slabs and masonry walls. Beams and slabs may be strengthened in flexure by bonding FRP strips at the soffit portion along the axis of bending. Shear strengthening of beams may be achieved by bonding vertical or inclined strips of FRP at the side faces of beams.

II. MATERIALS

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 to give compressive strengths of 15 to 35 MPa. Ordinary 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 12mm diameter and 10mm diameter were used as hanger bars. . The stirrups were made from mild steel bars with 8mm diameter.

2.3 Fiber Reinforced Polymer

Continuous fiber- reinforced materials with polymeric matrix (FRP) can be considered as composite, heterogeneous, and anisotropic materials with prevalent linear elastic behavior up to failure.

2.3.1 Glass Fibers

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 ($SiO2$) with a tetrahedral structure ($SiO4$).

FIG.1 GLASS FIBER

2.3.2 Fiber Sheet

Fiber sheet in this experimental investigation was E- glass, Bi directional 2oven woven mat. It was not susceptible to atmospheric agents. It was also chemically resistive and anticorrosive.

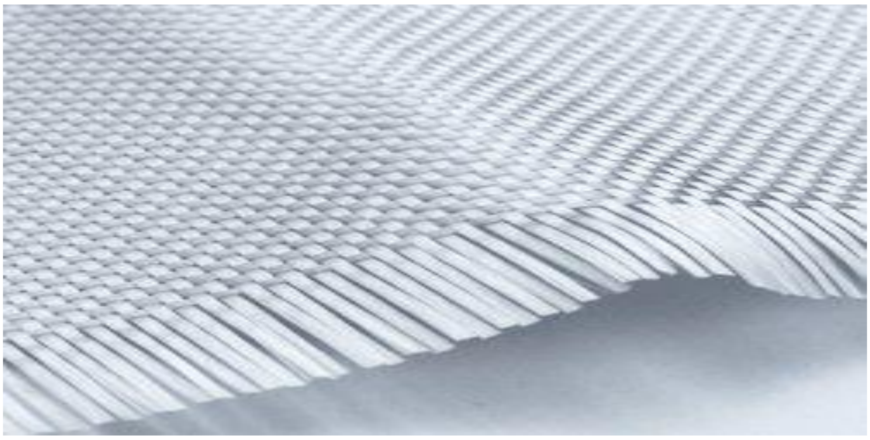


FIG. 2 GLASS FIBER WOVEN MAT

2.4 Epoxy Resin

Epoxy resins are relatively low molecular weight pre- polymers capable of being processed under a variety of conditions. The main advantages are that they can be partially cured and stored in that state and they exhibit low shrinkage during curing.

Viscosity of conventional epoxy resins is higher and they are more expensive compared to polyester resins.

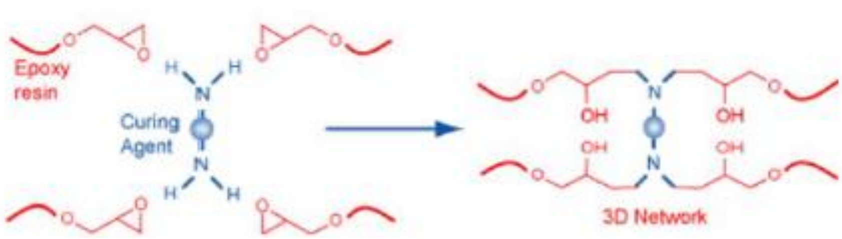


FIG 3 THE CURING OF EPOXY RESIN WITH PRIMARY AMINES

2.5 Strengthening 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. 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 24 hours at room temperature before testing.

FIG 5 APPLICATION OF EPOXY AND HARDENER ON THE BEAM

FIG 6 FIXING OF GFRP SHEET ON THE BEAM

2.6 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 the middle third for crack observations, deflection readings and possibly strain measurements is an important consideration, plates. The loading frame must be capable of carrying the expected test loads without significant distortion. Ease of access as is safety when failure occurs.

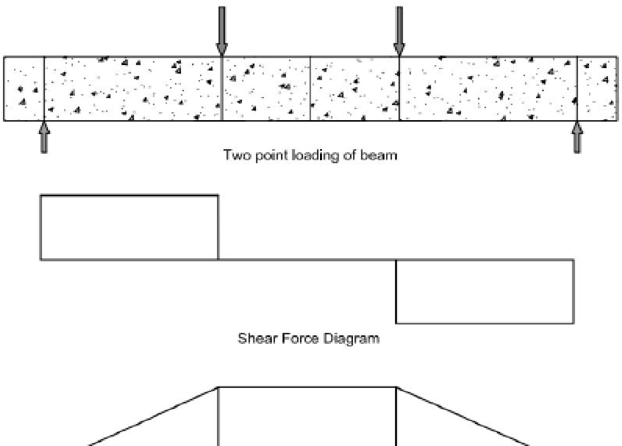


FIG 7 SHEAR FORCE AND BENDING MOMENT DIAGRAM FOR TWO POINT LOADING

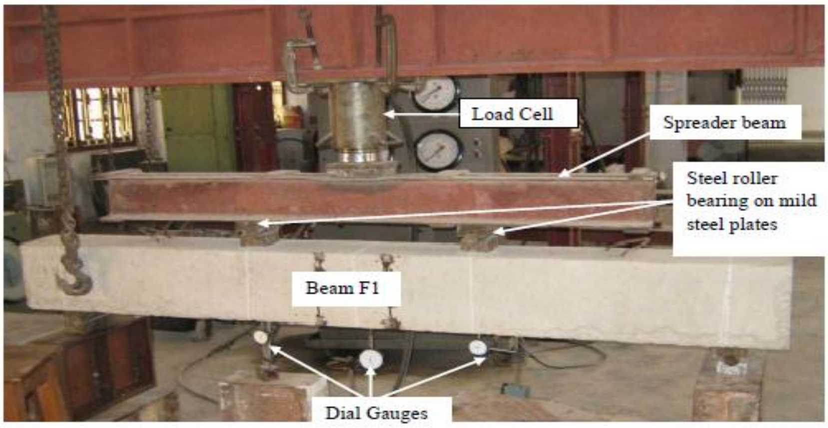


FIG 8 EXPERIMENTAL SETUP FOR TESTING OF BEAMS

III. PROJECT PROCEDURES

3.1 Cube Compressive Strength

Compressive strength is the capacity of a material or the ability of a structure to withstand load tending to reduce size .For compression test cube specimen of concrete and 150 mm x 150 mm were used respectively. Totally 21 cubes were cast 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 21 days and 28 days of curing for concrete compression testing

(1) Compressive strength at failure= $\frac{Load\ at\ failure}{area\ of\ compression\ face}$

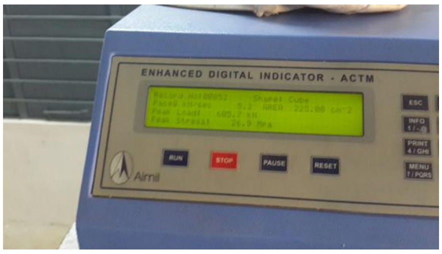


FIG 9 COMPRESSION TEST FOR THE CUBE ON 7 DAYS CURING

3.2 Specimen preparation

Formwork making use of plywood was prepared for the beam as per the required size. A total of 6 beams were cast wherein 2 were controlled specimens and 2 were subjected to U-wrapping and other 2 specimens were subjected to complete 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 24 hours, 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.

Linear variable displacement transducer (LVDT) was connected midspan of the beam to measure deflection. Crack widths were measured using a hand- held microscope with an optical magnification of 40X and a sensitivity of 0.01mm.

3.3 Shear Zone Wrapping

The beams after curing were wrapped using glass fiber reinforced polymer (GFRP) after applying primer 24 hours prior to wrapping. A mixture of epoxy resin was prepared wherein base, hardener and accelerator in the ratio of 0.5:1:5. During the preparation of the resin gloves and mask are worn as caution against burns.

3.3.1 U-wrapping

The beams after curing were wrapped using glass fibre reinforced polymer (GFRP) after applying primer 24 hours prior to wrapping.

A mixture of epoxy resin was prepared wherein base, hardener and accelerator in the ratio of 0.5:1:5. During the preparation of the resin gloves and mask are worn as caution against burns.

FIG 14 GFRP U-WRAPPING ON THE BEAM

FIG 15 BINDING OF WOVEN MAT OVER THE GFRP SHEETS

A coat of the epoxy resin is coated on the shear zone of the beams and on the base of the beams and after that before the resin sets. A coat of GFRP is binded on the shear zone which is at a distance of $\frac{Wl}{3}$ from either ends of the beam and the base and further poke joined using a paint brush once the GFRP sets on. The woven mat is coated on top of the GFRP coat using polyester resin.

After 24 hours the beam is tested in 2 point frame under 2 point loading and the ultimate load is applied until the strengthened beam get cracked i.e., tested till peak load and readings are recorded.

FIG 16 TESTING OF BEAM AFTER STRENGTHENING

3.3.2 Full wrapping

The beams after curing were wrapped using glass fiber reinforced polymer (GFRP) after applying primer 24 hours prior to wrapping.

A mixture of epoxy of resin was prepared wherein base, hardener and accelerator in the ratio 0.5:1:5. During the preparation of the resin gloves and mask are worn as caution against burns.

A coat of epoxy resin is coated on the entire beam and after that before the resin sets a coat of GFRP is binded on the entire beam and poke joined it using a paint brush. After 24 hours the beam is tested in 2 point frame under 2 point loading and readings were recorded just like in U-wrapping.

FIG 17 GFRP FULL WRAPPING

FIG 18 TESTING OF FULLY WRAPPED BEAM

IV. RESULTS AND GRAPHS

4.1 Compressive Strength of Cube

4.1.1 Compressive Strength of cube on 7days for M30 grade Concrete

TABLE 3
COMPRESSIVE STRENGTH OF CUBE ON 7DAYS FOR M30 GRADE CONCRETE

SL.NO	SPECIMEN NO	COMPRESSIVE STRENGTH
1	1	26.9MPa
2	2	26.8Mpa
3	3	26.9MPa

Compressive Strength of cube on 7day=26.9Mpa

4.1.2 Compressive Strength of cube on 14days for M30 grade Concrete

TABLE 4
COMPRESSIVE STRENGTH OF CUBE ON 28DAYS FOR M30 GRADE CONCRETE

SL.NO	SPECIMEN NO	COMPRESSIVE STRENGTH
1	1	29.9MPa
2	2	30.8Mpa
3	3	29.8MPa

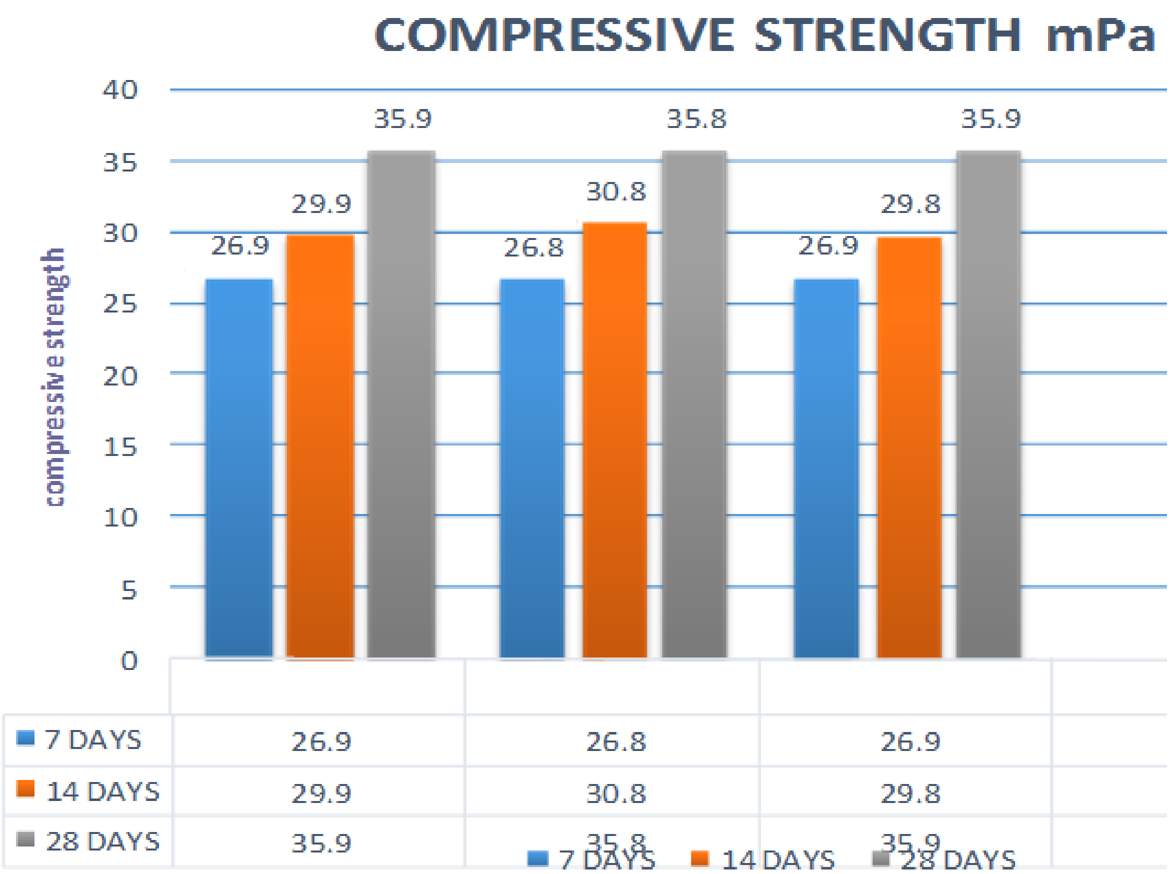
Compressive Strength of cube on 14day=29.9Mpa

4.1.3 Compressive Strength of cube on 28days for M30 grade Concrete

TABLE 5
COMPRESSIVE STRENGTH OF CUBE ON 28DAYS FOR M30 GRADE CONCRETE

SL.NO	SPECIMEN NO	COMPRESSIVE STRENGTH
1	1	35.9MPa
2	2	35.8Mpa
3	3	35.9MPa

Compressive Strength of cube on 28 day for M30 grade concrete=35.9Mpa



GRAPH 1: COMPRESSIVE STRENGTH (MPA)

4.2 Beam Results

4.2.1 Ultimate Load and Nature Of Failure

TABLE 7
ULTIMATE LOAD AND NATURE OF FAILURE

S. No	Type of Beam	Beam Designation	Load at initial crack(kN)	Ultimate Load(kN)	Nature of Failure
1.	Beam weak in shear	Control beam	165.7	178.3	Shear Failure
		Full wrapped with woven mat	154	198	GFRP rupture+ shear failure
		U- wrapped with woven mat	208	221	GFRP rupture + shear failure

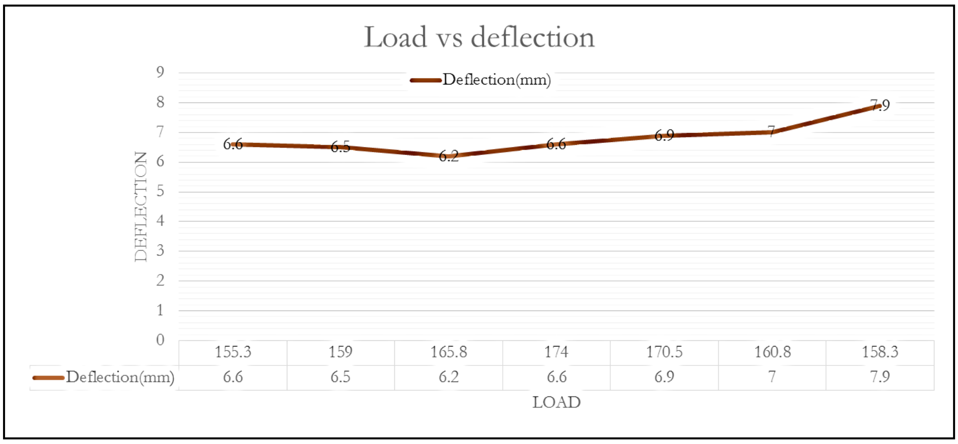
4.2.2 Ductility Behaviour

TABLE 8
EXPERIMENTAL DISPLACEMENT DUCTILITY

Beam no	Yield stage displacement Δy		Yield stage displacement Δu		Displacement ductility ratio $\left(\frac{\Delta u}{\Delta y}\right)$
	Moment (kNm)	Deflection (mm)	Moment (kNm)	Deflection (mm)	
Fully wrapped	25.66	6	33	7.2	1.2
U- wrapped	34.66	6.7	36.833	6.9	1.02

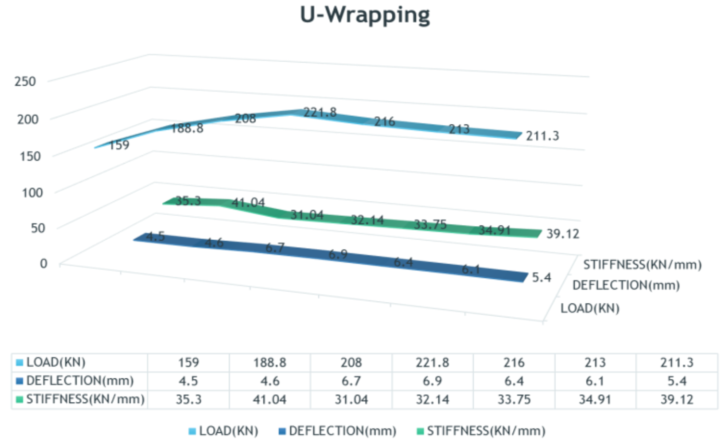
4.2.3 Graphical Result

4.2.3.1 Controlled Beam



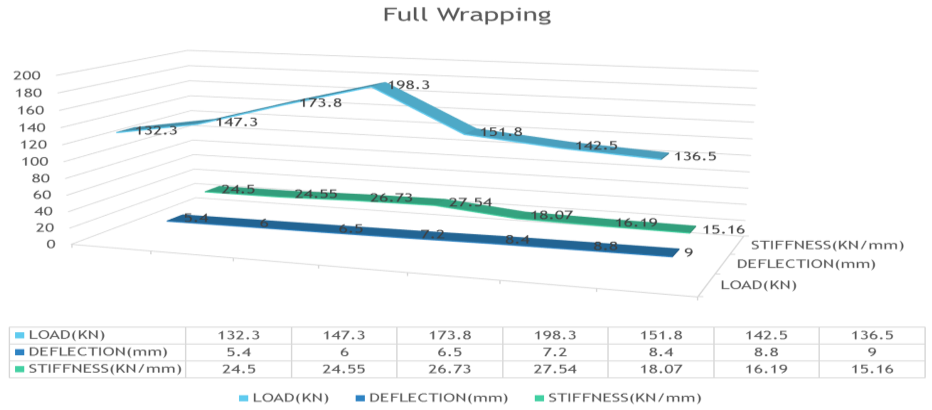
GRAPH 2 LOAD VS DEFLECTION FOR CONTROLLED SHEAR BEAM

4.2.3.2 U-Wrapping



GRAPH 3 LOAD VS DEFLECTION FOR U-WRAPPING

4.2.3.3 Full Wrapping



GRAPH 4 LOAD VS DEFLECTION FOR FULL WRAPPING

V. CONCLUSION

A set of 6 beams were cast out of which two were controlled beams and two were fully wrapped with GFRP and the two were U-wrapped with glass fiber and covered with woven mat. No horizontal cracks were observed at the level of the reinforcement, which indicated that there were no occurrences of bond failure. The observed results indicate that the external confinement using Glass Fibre Reinforced Polymer (GFRP) enhances the mechanical properties of Reinforced Concrete specimens, in different amount according to the FRP type, concrete properties and cross-section shape. And considerable strength was obtained for GFRP composite beam rather than R.C beam.

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REFERENCES

[1] Gyuseon Kim, Jongsung Sim and Hongseob Oh (2008). Shear strength of strengthened RC beams with FRPs in shear.

[2] Oral Buyukozturk, Oguz Gunes and Erdem Karaca (2004). Progress on understanding deboning problems in reinforced concrete and steel members strengthened using FRP composites.

[3] Shit, T.2011. Experimental and Numerical Study on Behavior of Externally Bonded RC T-Beams Using GFRP Composites.

[4] Bousselham, A., and Chaallal, O., (2004), "Shear Strengthening Reinforced Concrete Beams with Fiber-Reinforced Polymer

[5] Matthys, S., and Triantafillou, T., (2001), "Shear and Torsion Strengthening with Externally Bonded FRP Reinforcement.