International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 04 | Apr 2021 www.irjet.net p-ISSN: 2395-0072

EXPERIMENTAL AND NUMERICAL STUDY ON BEHAVIOR OF EXTERNALLY BONDED RC BEAMS USING GFRP SHEETS

Duraisamy R [1], Prof .S. Sundari [2]

[1]PG Scholar, Department of Civil Engineering, Government College of Engineering, Salem-11, Tamil Nadu, India
[2]Assistant Professor (CAS), Department of Civil Engineering, Government College of Engineering, Salem-11, Tamil Nadu, India

---

Abstract- *Reinforced concrete beams externally bonded with GFRP sheets were tested to failure using a symmetrical two point static loading system. Five RC beams were casted for this experimental test. All of them were weak in flexure and shears were having same reinforcement detailing. One beam was used as a control beam and four beams were strengthened using of glass fiber reinforced polymer (GFRP) sheets. Experimental data on load, deflection and failure modes of each of the beams were obtained. The effect of different amount and configuration of GFRP on ultimate load carrying capacity and failure mode of the beams were investigated.*

Key Words: *GFRP, flexural capacity, ultimate load carrying capacity*

1. INTRODUCTION

Deterioration in concrete structures is a major challenge faced by the infrastructure and bridge industries worldwide. The deterioration is mainly due to environmental effects, which includes corrosion of steel, gradual loss of strength with ageing, repeated high intensity loading, variation in temperature, freeze-thaw cycles, contact with chemicals and saline water and exposure to ultra-violet radiations. This problem, coupled with revisions in structural codes needed to account for the natural phenomena like earthquakes or environmental deteriorating forces, demands development of successful structural retrofit technologies. The structural retrofit problem has two options, repair/retrofit or demolition/reconstruction.

1.1 MATERIAL TESTING

The testing of the ingredient materials of concrete such as cement, fine aggregate and coarse aggregate is carried out and results are presented below.

A) TESTING OF CEMENT

Type: ordinary Portland cement. (Opc-53)

1. Specific gravity: 3.15
2. Normal Consistency: 26%
3. Setting Times: Initial: 97 minutes
   Final: 520 minutes
4. Soundness: 2 mm expansion
5. Fineness: 1 gm retained in 90 micron sieve

B) TESTING OF FINE AGGREGATE

1. Sieve Analysis the results of sieve analysis for fine aggregate are furnished in table 1 Grading Zone = II
2. Specific Gravity: 2.65
3. Water Absorption: .1%

C) TESTING OF COARSE AGGREGATE

1. Sieve Analysis the results of sieve analysis of coarse aggregate are furnished in table 4.2
2. Specific gravity = 2.72
3. Absorption value = 0.5%

Table -1: Results of Sieve Analysis for Fine Aggregate

Sl. No.	Sieve size (in mm)	Mass retained (in gm)	Mass passing (in gm)	% passing	Remarks
1	4.75	0	500	100	99-100
2	2.36	8	492	98.4	85-100
3	1.18	113	379	75.8	75-100
4	600 µ	71	308	61.6	60-79
5	300µ	183	125	25	12-40
6	150µ	119	15	3	0-10
7	Pan	15	0	-	-

D) MIX DESIGN OF M20 GRADE CONCRETE

1. Design Stipulations:-
a) Characteristics strength = 20N/mm2
b) Degree of quality control = Good
c) Degree of exposure = Moderate
d) Workability = 105mm
2. Materials Supplied:-
a) Cement: ordinary Portland cement. (Opc-53)
b) Course aggregate: 20mm down

c) Fine aggregate: Sand conforming to grading zone II Design Mix Proportions:-

Table - 2: Results of Sieve Analysis for Coarse Aggregate (20mm)

Sl. No.	Sieve size (in mm)	Mass retained (in gm)	Mass passing (in gm)	% passing	Remarks
1	80	0	5000	100	-
2	40	0	5000	100	-
3	20	406	4594	91.88	95-100
4	10	3028	1566	31.33	25-55
5	4.75	1822	141	2.82	0-10
6	Pan	141	0	0	-

Table -3: Results of Sieve Analysis for Coarse Aggregate (12.5mm)

Sl. No.	Sieve size (in mm)	Mass retained (in gm)	Mass passing (in gm)	% passing	Remarks
1	80	0	5000	100	-
2	40	0	5000	100	-
3	20	45	4955	99.1	-
4	12.5	751	4249	84.98	85-100
5	4.75	4131	73	1.46	0-20
6	Pan	73	0	0	-

E) REINFORCEMENT

High-Yield Strength Deformed bars of 10 mm diameter are used for the longitudinal reinforcement and 8 mm diameter high-yield strength deformed bars are used as stirrups. The yield strength of steel reinforcements used in this experimental program is determined by performing the standard tensile test on the three specimens of each bar.

Table 4: Results of Sieve Analysis for Coarse Aggregate (10mm)

Description	Cement	Sand (Fine Aggregate)	Course Aggregate	Water
Water Mix proportion (by weight)	1	1.755	3.02	0.5
Quantities of materials (in Kg/m3)	355	694.3	1073.323	177.5

Fig -1: Reinforcement Detailing of Beam

Fig -2: 3D View of Reinforcement Detailing Of Beam

1.2 STRENGTHENING OF BEAMS

At the time of bonding of fiber, the concrete surface is made rough using a coarse sand paper texture and then cleaned with an air blower to remove all dirt and debris. After that the epoxy resin is mixed in accordance with manufacturer's instructions. The mixing is carried out in a plastic container (mixing ratio 1:3 for eg: 30 gram of resin then add 10 grs for hardener to it). After their uniform mixing, the fabrics are cut according to the size then the epoxy resin is applied to the concrete surface. Then the GFRP sheet is placed on top of epoxy resin coating and the resin is squeezed through the roving of the fabric with the roller .Air bubbles entrapped at the epoxy/concrete or epoxy/fabric interface are eliminated. During hardening of the epoxy, a constant uniform pressure is applied on the composite fabric surface in order to extrude the excess epoxy resin and to ensure good contact between the epoxy, the concrete and the fabric.

Fig -3: Application of epoxy and hardener on the beam

Fig- 4: Fixing of GFRP sheets on the beam

2. EXPERIMENTAL SETUP

The beams are tested in the loading frame of the "Structural Engineering" Laboratory of Govt College of engineering, Salem. The testing procedure for the all the specimen is same. First the beams are cured for a period of 28 days then its surface is cleaned with the help of sand paper for clear visibility of cracks. The two-point loading arrangement is used for testing of beams. This has the advantage of a substantial region of nearly uniform moment coupled with very small shears, enabling the bending capacity of the central portion to be assessed. Two-point loading is conveniently provided by the arrangement shown in Figure. The load is transmitted through a load cell and spherical seating on to a spreader beam. The spreader beam is installed on rollers seated on steel plates bedded on the test member with cement in order to provide a smooth leveled surface. The test member is supported on roller bearings acting on similar spreader plates. The specimen is placed over the two steel rollers bearing leaving 50 mm from the ends of the beam. The remaining 1000 mm is divided into three equal parts of 333 mm as shown in the figure 5.

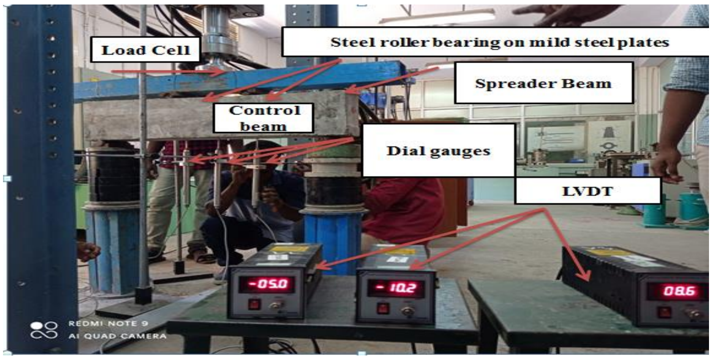

Fig -5: Experimental Setup

BEAM-1:

Fig6: Experimental Setup of the Control Beam 1

Table 5: Deflection Values of Control Beam1

S.NO	LOAD (KN)	At L/2	At L/3	REMARK
1	0	0	0	
2	10	1.1	0.9	
3	20	1.8	0.9	
4	30	2.1	1.7	Hairline cracks appeared
5	40	2.7	1.9	
6	50	3.2	2.7	
7	60	3.6	2.9	
8	70	4.1	3.1	
9	80	4.7	3.4	
10	90	5.3	3.7	Ultimate Load

11	100	-	-	
12	110	-	-	
13	120	-	-	
14	130	-	-	
15	140	-	-	

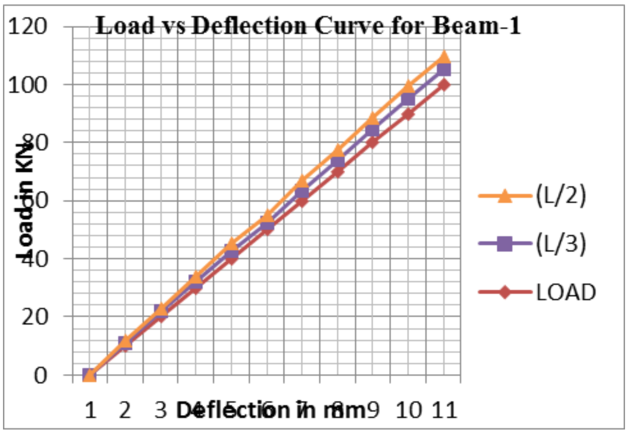

Chart-1: Load vs Deflection Curve for Beam-1

BEAM -2:

Fig- 7: Experimental Setup of the Beam 2

Table -6: Deflection Values of Beam 2

S.NO	LOAD (KN)	At L/2	At L/3	REMARK
1	0	0	0	
2	10	0.9	0.8	
3	20	1.3	1.1	
4	30	2.0	1.1	
5	40	2.5	1.8	
6	50	2.7	1.83	
7	60	3.1	1.9	
8	70	3.5	2.1	Debonding of fiber
9	80	3.5	2.7	
10	90	3.7	2.9	
11	100	3.81	2.93	Tearing of fiber
12	110	3.81	3.1	
13	120	3.81	3.1	
14	130	3.81	3.2	Tearing and debonding
15	140	3.81	3.5	Ultimate Load

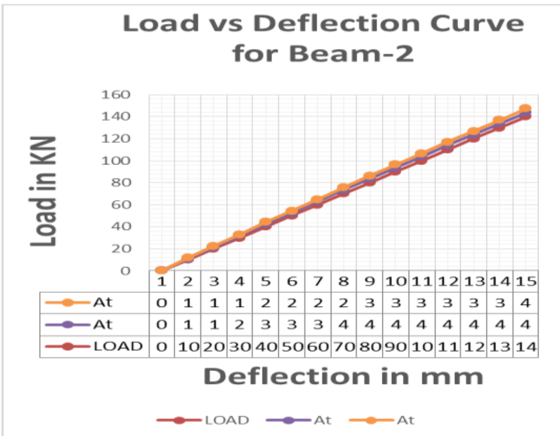

Chart- 2: Load vs. Deflection Curve for Beam 2

BEAM-3:

Fig -8: Experimental Setup of the Beam 3

S.NO	LOAD (KN)	At L/2	At L/3	REMARK
1	0	0	0	
2	10	0.9	0.7	
3	20	2.6	1.3	
4	30	2.9	2.3	
5	40	3.5	2.5	Hairline cracks appeared
6	50	3.7	2.8	
7	60	3.9	2.9	
8	70	4.0	3.1	
9	80	4.6	3.2	
10	90	5.1	3.2	
11	100	5.1	3.5	Debonding of fiber
12	110	5.2	3.54	
13	120	5.2	3.54	Ultimate Load
14	130	-	-	-

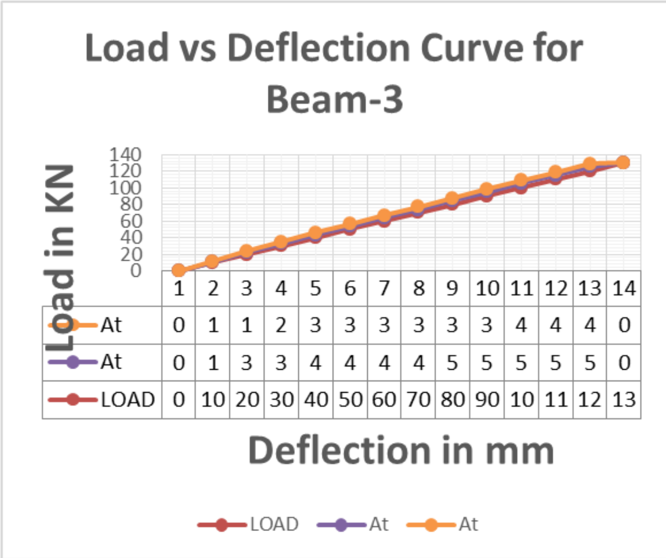

Chart-3: Load vs. Deflection Curve for Beam 3

BEAM-4

Fig-9: Experimental Setup of the beam4

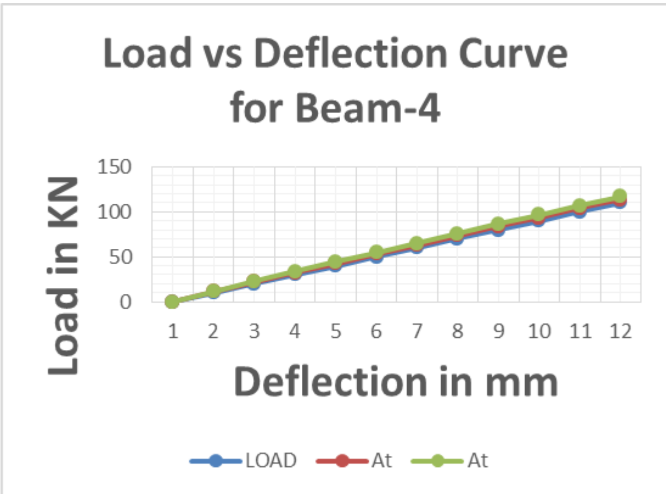

Chart-4: Load vs. Deflection Curve for Beam 4

Table- 8: deflection values of beam 4

S.NO	LOAD (KN)	At L/2	At L/3	REMARK
1	0	0	0	
2	10	1.1	0	
3	20	1.9	1.2	
4	30	2.1	1.3	
5	40	2.8	1.51	
6	50	3.1	1.6	
7	60	3.1	1.6	
8	70	3.6	1.9	
9	80	3.5	2.7	Debonding of fiber
10	90	3.51	3.1	
11	100	3.9	3.1	
12	110	3.8	3.2	Ultimate Load
13	120	-	-	
14	130	-	-	
15	140	-	-	

Fig- 10: Crack formed after initial loading in Beam

S.NO	LOAD (KN)	At L/2	At L/3	REMARK
1	0	0	0	
2	10	1.1	0.3	
3	20	1.9	1.4	
4	30	2.0	1.4	
5	40	2.7	1.61	
6	50	3.6	1.62	
7	60	3.7	1.9	
8	70	3.7	2.1	
9	80	3.9	2.4	Debonding of fiber
10	90	4.1	2.5	
11	100	4.2	2.9	Ultimate Load
12	110	-	-	
13	120	-	-	
14	130	-	-	

Table- 9: Deflection values of BEAM 5

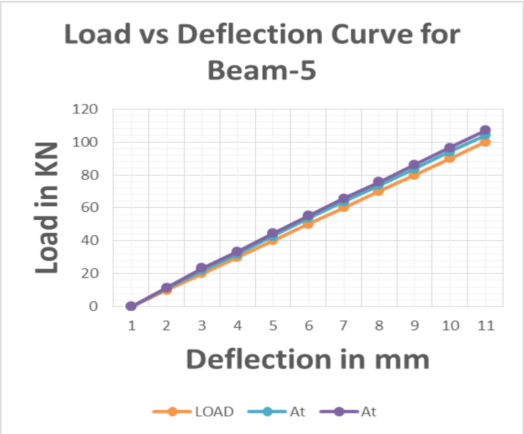

Chart-5: Load vs. Deflection Curve for Beam 5

ULTIMATE LOAD CARRING CAPACITY

The load carrying capacity of the control beams and the strengthen beam are plotted below. It is observed that beam 2 is having the max load carrying capacity.

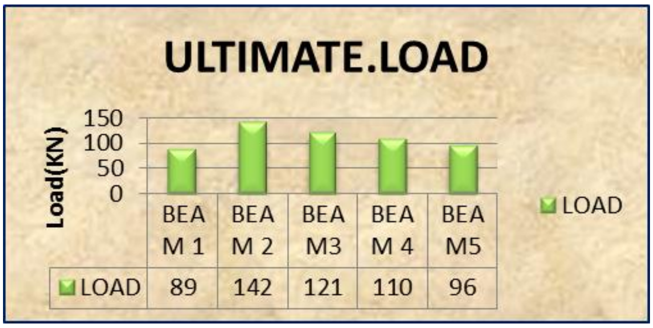

Chart-6: Ultimate Load carrying capacity

INCREASE IN LOAD CARRYING CAPACITY

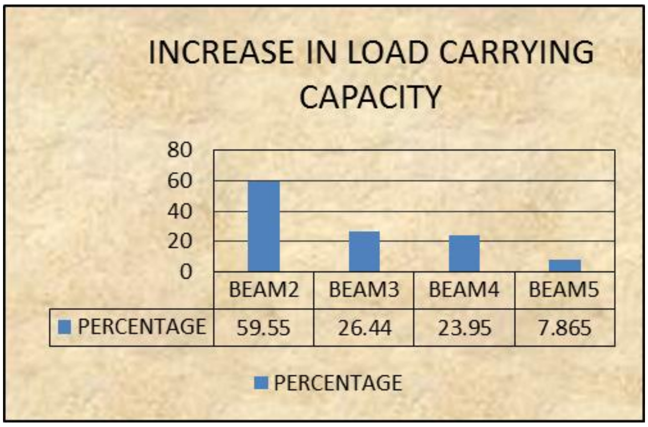

Chart-7: Percentage increase in the Ultimate Carrying capacity w.r.t Control Beam 1

From the above figure we can observe the amount of increase in the flexural strength for each strengthened beam with respect to the Control Beam 1

3. CONCLUSIONS

The present experimental study is done on the flexural behavior of reinforced concrete beams strengthened by GFRP sheets. five reinforced concrete (RC) beams weak in flexure having same reinforcement detailing are casted and tested. From the test results and calculated strength values, the following conclusions are drawn:

1. The ultimate load carrying capacity of all the strengthen beams were enhanced as compared to the Control Beam1.

2. Initial flexural cracks appear for higher loads in case of strengthened beams.

3. The load carrying capacity of the strengthened Beam 2 was found to be maximum of all the beams. It increased up to 59.55 % more than the control beam 1.

4. Beam 4 which was retrofitted in the U-wrapping showed minimum deflection values on same loads as compared to other strengthened beams and the control beam.

REFERENCES

1.Tarek H. Almusallam and Yousef A. Al-Salloum, Ultimate strength prediction of RC beams externally strengthened by composite materials, composite engineering, Feb-2001, Part-B, pp 609-19.

2. Y.C. Wang, C.H. Chen, Analytical study on reinforced concrete beams strengthened for flexure and shear with composite plates, 2003, Composite Structure, pp 13748.

3. Sergio F. Bren, Beth M. Macri, Effect of Carbon-Fiber Reinforced Polymer Laminate Configuration on the Behavior of Strengthened Reinforced Concrete Beams, May-June 2004Journal of Composites for Construction, pp 229-40.

4. Hsuan-Teh Hu, Fu-Ming Lin and Yih-Yuan Jan, Nonlinear finite element analysis of reinforced concrete beams strengthened by fiber-reinforced plastics, 2004, Composite Structure, pp 271-81.

5. J. Lundqvist, H. Nordin, B. Täljsten and T. Olofsson, Numerical analysis of concrete beams strengthened with CFRP– a study of anchorage lengths, 2005, International Institute for FRP in Construction.