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Experimental Investigation of Reinforced Concrete T-Beam using GFRP composites

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Abstract: Due to deterioration of concrete civil engineers need some alternative techniques to save lots of the structure. During this research the effect of fiber reinforced polymer (FRP) composites are studied on the varied loading condition by covering FRP [7] sheets along the varied structure members. During this experimental study five ferroconcrete T beams were casted and every one five beams were weak in flexure, out of those one is taken as controlled and other beams were strengthened by using continuous optical fiber reinforced polymer (GFRP) sheets in flexure zone.

Keywords: Deterioration, GFRP, Consistency, HYSD Bar, Flexure

I. INTRODUCTION

The major challenged faced by the civil engineers worldwide is Deterioration in concrete structures. The most explanation for deterioration is due to some natural environmental effects like corrosion of steel rebars, loss of strength by time decay, repeated altered loading, temperature variation, freezing-thawing cycles , chemically contact /saline water and exposure to sun radiations.

Due to this deterioration there's a requirement for structural retrofit technologies [1], these technologies have many options but two are best i.e. retrofit and reconstruction. However, with the introduction of latest composite materials like fibre reinforced polymer (FRP) composites, concrete members can now be easily and effectively strengthened using externally bonded FRP composites.

Retrofitting of concrete structures with covering FRP sheets provide a less expensive and technically superior alternative to the normal techniques in many situations due to high strength, low weight, corrosion resistance, high fatigue resistance, easy and rapid installation and nominal change in structural geometry.

II. MATERIAL USED

The material used for creating concrete are generally cement (binding material), sand, coarse [3] aggregate, fine aggregate [3], potable water [2] and sometimes admixture if needed.

2.1Properties of materials

The cement took during this research work was OPC 43 grade [4], supplied by Shree cement ltd. with the varied technical specification as shown

Table 1: Specification of Binding Material

S.No	Property	Value
1	Specific gravity	2.96
2	Normal Consistency	32%
3	Setting Time : Initial	95 min
4	Setting Time : final	450min
5	Soundness	3mm expansion
6	Fineness	2 gm retained in 90 micron sieve

Table 2: Sieve Analysis for Fine Aggregate sample (2000gm)

Sl. No.	Sieve size (in mm)	Mass retained (in gm)	Mass passing (in gm)	% passing	Remarks
1	4.75	20	1980	99	90-100
2	2.36	44	1936	96.8	85-100
3	1.18	132	1804	90.2	75-100

4	600µ	346	1458	72.9	60-79
5	300µ	1216	242	12.1	12-40
6	150µ	202	40	2	0-10
7	Pan	40	0	0	--

Specific Gravity: 2.67 and Water Absorption: 8%

Table 3: Sieve Analysis for Coarse Aggregate (20mm) (5000gm)

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	436	4564	91.28	95-100
4	10	3027	1537	30.74	25-55
5	4.75	1478	59	1.18	0-10
6	Pan	59	0	0	0

Table 4: Sieve Analysis for Coarse Aggregate (10mm)(5000gm)

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	54	4946	98.92	-
4	10	1122	3824	76.48	85-100
5	4.75	3678	146	2.92	0-20
6	Pan	146	0	0	0

2.2 Mix Design of M20 Grade Concrete [2]

Characteristics strength = 20 N/mm^2, Degree of internal control = Good, Degree of exposure = Mild, Workability = 62, Cement: Shree Portland Cement, Coarse Aggregate: 20 mm down, Fine Aggregate: Sand was conforming to grading zone III [3] as per IS 383.

Table 5: Design Mix Proportion

Description	Cement	Sand (Fine Aggregate)	Coarse Aggregate	Water
Mix proportion (by weight)	1	1.56	3.3	0.5
Quantities of materials (in Kg/m3)	372	580	1228	186

2.3 Reinforcement

High-Yield Strength Deformed bars [5] of 20 mm diameter were used for the longitudinal reinforcement and 8 mm diameter high-yield strength deformed bars were used as stirrups.

III. DETAILING OF REINFORCEMENT IN REINFORCE CONCRETE T- BEAMS

For all the five reinforced concrete T beams, the same arrangement for flexure and shear reinforcement was prepared. The tension reinforcement consists of 2-20 **Ø** HYSD bar [5]. 4-8**Ø** of HYSD bars were also provided as hang up bars. The shear reinforcement has Ø -8**,** 2-legged vertical stirrups of HYSD bars placed at 100mm c/c. The detailing of reinforcement of the beam is shown in Fig 1

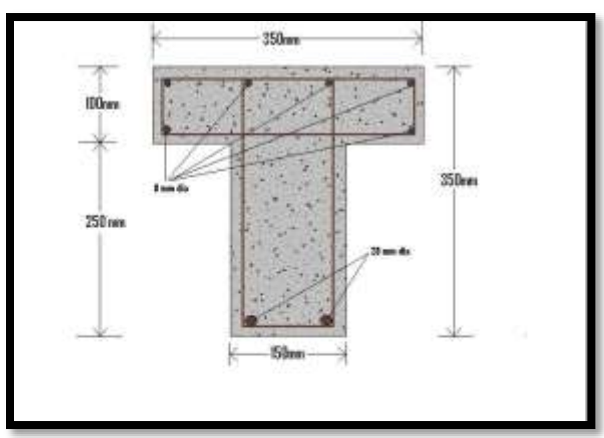

Fig 1: Front View of Reinforcement Detailing of T- Beam

IV. EXPERIMENTAL STUDY AND METHODOLOGY

- Five nos of RC- T beams were casted
- All the five beams were weak in flexure, from these five, one is taken as controlled beam and other beams were strengthened by using continuous optical fiber reinforced polymer (GFRP) sheets in flexure.
- The strengthening of the beams was through with different layers of GFRP sheets.
- Experimental data on the essential of load, deflection and failure modes of every of the beams was obtained and to be compared
- The proportion of various materials were taken as calculated in mix design
- The blending was administered with the assistance of concrete mixture
- The beams were cured for 28 days. For every sample of beam three cubes were casted to work out the compressive strength of concrete
- The grading zone of fine aggregate was zone III as per Indian Standard specifications with a specific gravity of two.67.
- **T**he coarse aggregates of two grades were used i.e. 10 mm and 20 mm size.
- Potable water was used.
- HYSD bars of twenty mm φ and eight mm φ were used.

Fig. 2: Moulds for casting of T-beam

V. CURING OF CONCRETE

- Curing was administered to avoid the loss of water which is important for the method of hydration and hence for hardening.
- It also prevents the exposure of concrete to a hot atmosphere and to drying winds which can cause quick drying out of moisture
- During this current experimental work curing was done by spraying water on the jute bags

VI. BEAMS STRENGTHENING PROCEDURE

- The concrete surface is brought rough by employing a coarse sand paper
- The whole dirty surface was cleaned with a steel

brush.

- The GFRP were cut according to the size then the epoxy was applied to the concrete faced.
- The GFRP sheet is placed on top of epoxy coating
- Fiber material was cured for twenty four hours at normal room temperature before testing.

Fig. 3: Epoxy application on beam

Fig 4: Fixing GFRP sheets

Fig 5: pressing to removal of air bubble

VII. EXPERIMENTAL SETUP AND PROCEDURE

- The T-beams were tested within the UTM of the engineering laboratory.
- The testing procedure for the all the specimen was uniform and same fitness.
- The curing time for every beam was 28 days.
- The two-point loading arrangement was used for trying the various values of beams.
- The load is transmitted uniformly through a loading cell [6] and spherical seating arrangement.

VIII. RESULTS AND DISCUSSION

8.1Beam No.1- Control Beam

Table 6: Deflection Values of Control Beam1

Load (in kN)	At Point L/3 (in mm)	At Point L/2 (in mm)	Remarks
0	0	0	
20	0.36	0.44	
30	0.53	0.63	
40	0.64	0.76	
50	0.75	0.89	
60	0.86	1.02	
70	1.00	1.20	
80	1.16	1.33	
90	1.29	1.54	
100	1.46	1.74	
110	1.58	1.88	
120	1.78	2.10	Hairline crack started
130	1.91	2.23	
140	2.06	2.40	
150	2.19	2.52	
160	2.34	2.73	
170	2.54	2.95	
180	2.73	3.16	
190	2.87	3.32	
200	3.01	3.48	
210	3.14	3.63	
225	3.38	3.88	
240	3.63	4.17	Ultimate Load

8.2Beam-2 Single Layered GFRP bonded at bottom of Web from one end to another end

Table 7: Deflection Values of Beam 2

Load (in Kn)	At Point L/3 (in mm)	At Point L/2 (in mm)	Remarks
0	0	0	
20	0.26	0.31	
30	0.36	0.44	
40	0.45	0.55	
50	0.56	0.67	
60	0.72	0.87	
70	0.82	0.99	
80	0.97	1.17	
90	1.12	1.33	
100	1.28	1.51	
110	1.4	1.65	
120	1.57	1.85	
130	1.7	1.99	Hairline cracks appeared
140	1.84	2.15	
150	2	2.32	
160	2.16	2.49	
170	2.32	2.66	
180	2.45	2.81	Debonding of fiber
190	2.61	2.98	
200	2.74	3.1	
210	2.84	3.23	
220	3	3.39	
230	3.1	3.54	
240	3.25	3.68	
250	3.38	3.82	
260	3.5	3.98	
270	3.65	4.14	
276	4.07	4.68	Tearing of fiber
290	4.53	5.4	
308			Tearing and Deboning
310			Ultimate Load

Table 8: Beam 3 Deflection Values

Load (in Kn)	At Point L/3 (in mm)	At Point L/2 (in mm)	Remarks
0	0	0	
20	0.27	0.29	
30	0.35	0.38	
40	0.45	0.50	
50	0.56	0.61	
60	0.68	0.74	
70	0.78	0.85	
80	0.92	1.00	
90	1.03	1.14	
100	1.19	1.32	
110	1.28	1.41	
120	1.42	1.58	
130	1.55	1.73	Hair line crack appeared
140	1.80	2.00	
150	1.90	2.11	
160	2.13	2.36	
170	2.27	2.50	
180	2.48	2.71	
190	2.60	2.85	
200	2.78	3.04	
210	2.95	3.21	
220	3.10	3.37	
230	3.28	3.58	
240	3.43	3.74	
250	3.61	3.93	
260	3.80	4.11	
270	4.20	4.50	Debonding occurred
290		Ultimate load	Debonding but no tearing

8.3 Beam-3 Single Layered GFRP bonded at Bottom of Web from L/3 to L/2

8.4 Beam-4 ,U- Jacketed lone Layered GFRP bonded from end to end

Table 9: deflection values of beam 4

Load (in Kn)	At Point L/3 (in mm)	At Point L/2 (in mm)	Remarks
0	0	0	
20	0.28	0.24	
30	0.38	0.35	
40	0.49	0.45	
50	0.59	0.58	
60	0.69	0.71	
70	0.84	0.89	
80	0.95	1.03	
90	1.10	1.20	
100	1.25	1.37	
110	1.38	1.53	
120	1.56	1.17	
130	1.72	1.88	
140	1.84	2.04	
150	1.98	2.18	
160	2.13	2.35	
170	2.28	2.51	
180	2.48	2.75	
190	2.63	2.92	
200	2.79	3.10	
210	2.95	3.26	
220	3.08	3.43	
230	3.26	3.63	
240	3.41	.78	
250	3.55	3.96	
260	3.73	4.15	
270	4.65	5.40	
280	6.95	7.60	
290			Tearing started
318			Tearing and Debonding started simultaneously
330			Ultimate Load

8.5 Beam-5, U- Jacketed Single Layered GFRP retrofitted on cracked beam from end to end

Table 10: Deflection of Beam 5(before retrofitting)

Load (in Kn)	At Point L/3 (in mm)	At Point L/2 (in mm)	Remarks
0	0	0	
20	0.38	0.42	
30	0.45	0.52	
40	0.54	0.63	
50	0.64	0.75	
60	0.75	0.86	
70	0.85	0.98	
80	0.96	1.12	
90	1.08	1.28	
100	1.21	1.41	
110	1.35	1.58	
120	1.49	1.73	
130	1.63	1.88	
140	1.79	2.05	
150	1.96	2.25	

Table 11 Deflection of Beam-5(after retrofitting)

Load (in Kn)	At Point L/3 (in mm)	At Point L/2 (in mm)	Remarks
0	0	0	
20	0.44	0.45	
30	0.53	0.55	
40	0.65	0.68	
50	0.79	0.83	
60	0.90	0.96	
70	1.01	1.09	
80	1.13	1.22	
90	1.24	1.36	
100	1.35	1.48	
110	1.46	1.60	
120	1.58	1.72	
130	1.69	1.84	
140	1.81	1.96	
150	1.93	2.10	
160	2.05	2.22	
170	2.19	2.38	

180	2.31	2.55	
190	2.52	2.72	
200	2.68	2.89	
210	2.82	3.06	
220	2.98	3.23	
230	3.14	3.41	
240	3.32	3.62	
250	3.48	3.78	
260	3.68	4.01	
270			Debonding
306			Tearing
326			Ultimate

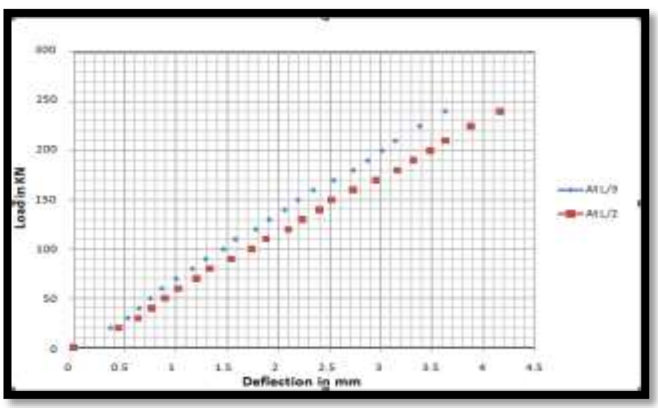

Fig.6: Load vs. Deflection Curve for Control Beam 1

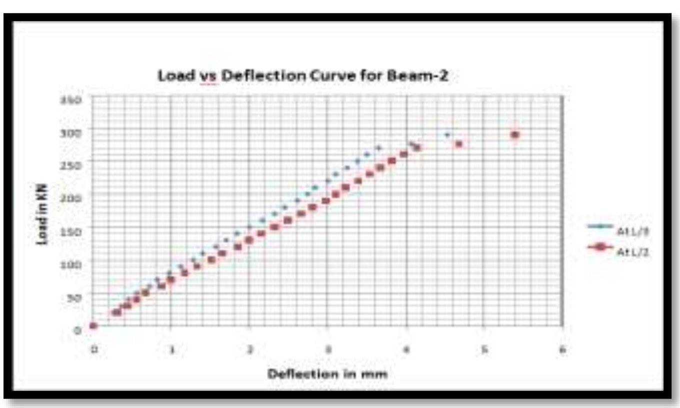

Fig.7: Load vs. Deflection Curve for Control Beam 2

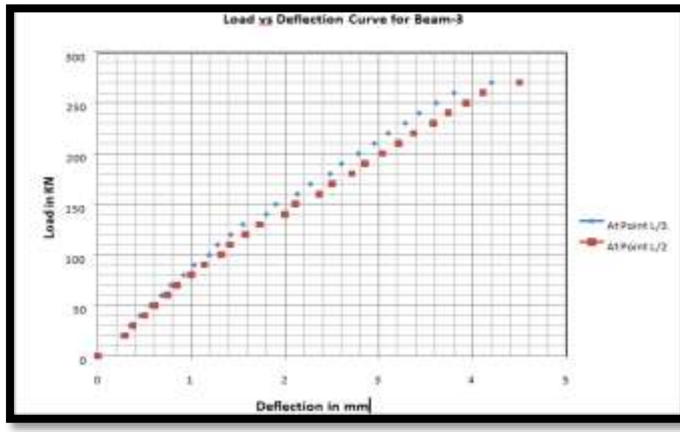

Fig.8: Load vs. Deflection Curve for Control Beam 3

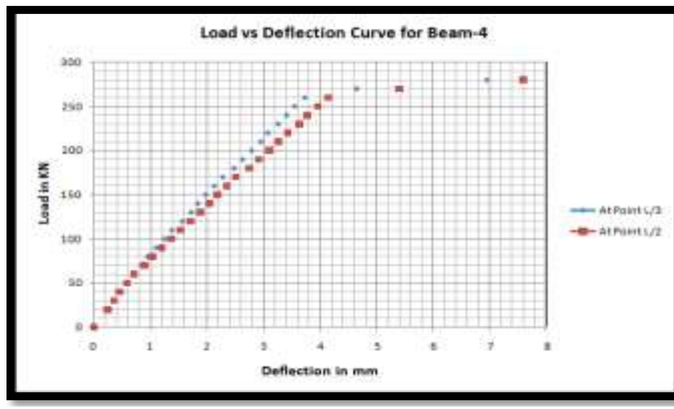

Fig.9: Load vs. Deflection Curve for Control Beam 4

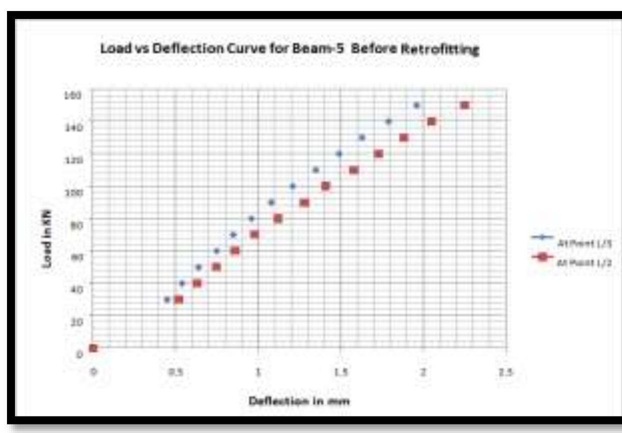

Fig.9: Deflection Curve for Control Beam 5 before retrofitting

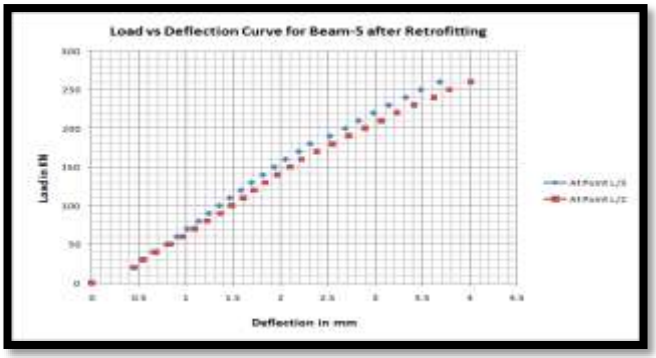

Fig.10: Load vs. Deflection Curve for Control Beam 5 after retrofitting

IX. CONCLUSIONS

The following silent conclusions were drawn from the current experimental study

1. The ultimate load carrying capacity of all the strengthen beams were improved as compared to the Control Beam 1
2. Initial flexural cracks appear for higher loads in case of FRP strengthened beams.
3. The load carrying capacity of the strengthened Beam 4 was found to be maximum and was increased to 37.5 % more than the control beam 1, 6.5% more than Strengthened beam 2 and 4.4 % more than the strengthened beam 5.
4. Beam which was retrofitted in the web part only for 1 m length in the center showed minimum deflection values on same loads as compared to other strengthened beams and therefore control beam.
5. Flexural strengthening in the web part throughout the length of the beam increases the last load carrying capacity

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