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Study on Flexural Behaviour of RC Beams with Extra Addition of Glass Fibre and CFRP Composites under Flexural Loading

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Abstract : The damaged or old structures are sometime need to be repaired or reinforced to enhance its structural performances and life. CFRP laminates are new carbon-based composite materials that are attach externally to the concrete beams. The use of Carbon fiber reinforced polymer materials for structural repair and strengthening has continuously increased in recent years, due to several advantages associated with these composites, while comparing with conventional materials. These high strength material improves the bending behaviour of beams. The process of mechanical clamping is done on the precracked CFRP wrapped beams and the strength features are also monitored in the same loading setup. This is achieved by providing a steel frame around the cracked beams at tension zones.
Keywords : CFRP, laminates, flexural behavior, failure modes, glass fiber forced concrete (GFRP concrete), Strengthening, composite materials.

Introduction

Reinforced cement concrete is an extremely popular construction material used for structural components of a building like beams, columns and slabs etc. One major flaw of RCC is its susceptibility to environmental attack. This can severely decrease the strength and life of the structures. The repair of structurally deteriorated RC Structures become necessary since the structural element ceases to provide satisfactory strength and serviceability. Some of these structures are in such a bad condition that they need to be replaced. Additional strength may be needed to allow for higher loads to be placed on the structure. This is often required when the use of the structure changes and a higher load carrying capacity is needed. This can also occur if additional mechanical equipment, filing systems, planters or other items are being added to the structure.

Two techniques are typically adopted for the strengthening of beams, relating to the strength enhancement desired, and flexural strengthening. In many cases it may be necessary to provide both strength enhancements. For the flexural strengthening of a beam, Glass fibre and CFRP sheets are applied to the tension face of the member (the bottom face for a simply supported member with applied top loading or gravity loading). Principal tensile fibers are oriented in the beam longitudinal axis, similar to its internal flexural steel reinforcement. This increases the beam strength and its stiffness (load required to cause unit deflection), however decreases the deflection capacity.

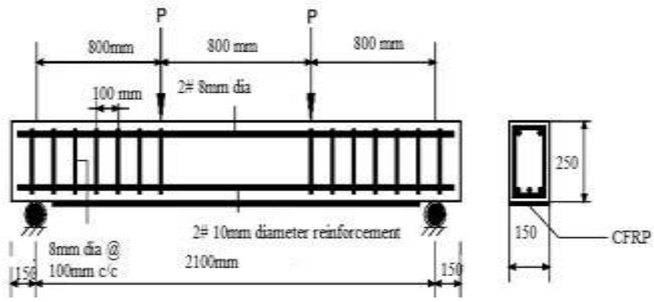

Fig 1. Reinforcement details for beam

Padmarajaiah and Ramaswamy [1], shows the effects of adding fibre to concrete increase the compressive strength. In that research, addition of 1.5 % of fibres in volume, increase the compressive strength of concrete up to 15% when compared with normal concrete. So the glass fibre is added to it (in addition) to increase the strength of the concrete.

Experimental Program

A. Materials Used:

Cement

Ordinary Portland Cement OF 53 grade available in local market is used in the investigation of this project. The cement used in this project is tested for various proportions as per IS: 4031 – 1988 and conforming to specifications of IS: 12269 – 1987. The properties of cement are given below.

Table I - Properties of Cement

SI. No	Properties	Results
1	Specific gravity	3.16
2	Initial setting time(min)	30
3	Final setting time(min)	600

Coarse aggregate

Crushed angular stones from a local source was used as Coarse aggregate. The coarse aggregate used here is 20 mm aggregate of good quality.

Table II - Properties of Coarse aggregate

SI. No	Properties	Results
1	Specific gravity	2.74
2	Water Absorption	4%
3	Fineness modulus	1.96
4	Flakiness index	4.58%
5	Elongation index	3.96%

Fine aggregate

Natural river sand was used as fine aggregate.

Table III - Properties of Fine aggregate

SI. No	Properties	Results
1	Specific gravity	2.60
2	Water Absorption	70%
3	Fineness modulus	2.6

Glass fibre

The glass fibres used are CEM-FIL Anti-Crack HD. It has very high tensile strength 1020 to 4800 N/mm^2.

Table IV - Properties of Glass Fibre

SI. No	Properties	Results
1	Modulus of elasticity	72 Gpa
2	Diameter	14 microns
3	Specific gravity	2.68
4	Length	12 mm
5	Aspect ratio	857.1
6	Number of fibresper kg	212 million

Test Methods

The flexural behaviour of the reinforced concrete beam is observed under two point loading. The test data are recorded and it will be interpreted for further comparison with CFRP wrapped beams. The reinforced concrete beam with glass fibre mixes is tested under the same loading conditions. The point at which the cracks occurred is noticed and the flexural strength of the beam is noted. The precrackedbeams is wrapped with CFRP laminates by using epoxy resins. Then the wrapped concrete samples is allow to cure for one week. This concrete specimen is again tested with the same loading setup. The result data are tabulated, interpreted and the discussions are made based on the observed results. The test process of control beam and retrofitted beams are shown in figures.

Fig 4. Testing of control beam (concrete with glass fibre without wrapping)

Fig 5. Deflection and Crack patterns observed in control beam under loading

Fig 6. CFRP fully wrapped on its tension zone of precracked beam

Fig 7. Cracks formation on CFRP wrapped concrete beam

Fig 8. Fully wrapped beam with mechanical clamp

Results & Discussion

Results shows that as the addition of glass fibre increases the strength. The test results of concrete beams with glass fibre mixes, fully wrapping and mechanical clamping are shown in

TableV Load Mid-span deflection – control beam

Load	Left	Mid	Right
0	0	0	0
0.5	0.12	0.63	0.15
1	0.54	0.90	0.53
1.5	1.27	1.63	1.28

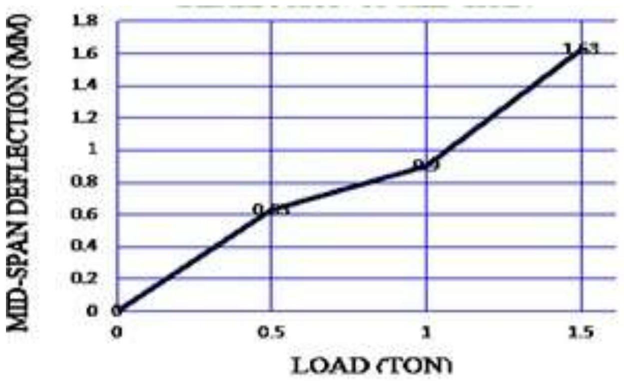

Fig 9. Deflection at mid span of CB

TableVI Load Mid-span deflection – FWB (Single)

LOAD	LEFT	MID	RIGHT
0	0	0	0
0.3	0.24	0.28	0.24
0.6	0.47	0.52	0.47
0.9	0.73	0.89	0.67
1.2	0.87	1.16	0.87
1.5	1.47	1.97	1.42
1.8	1.58	2.19	1.58
2.1	1.98	2.72	1.98
2.4	2.45	3.36	2.35
2.7	2.82	4.07	2.82
3	3.18	4.5	3.18
3.3	3.42	5.07	3.4
3.6	3.83	5.52	3.83
3.9	4.28	6.17	4.28
4.2	4.68	6.76	4.68
4.5	5.24	7.52	5.17
4.8	5.75	8.21	5.6

Ultimate Load-5.4 TON

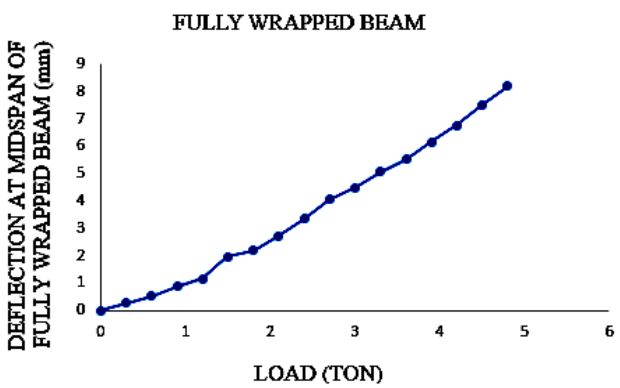

Fig 9. Deflection at mid span of FWB

Table VII Load Mid-span deflection – FWB (DOUBLE)

Load	Left	Mid	Right
0	0	0	0
0.3	0.25	0.27	0.25
0.6	0.44	0.48	0.44
0.9	0.61	0.75	0.61
1.2	0.82	0.95	0.82
1.5	1.18	1.36	1.18
1.8	1.52	1.81	1.52
2.1	1.94	2.32	1.94
2.4	2.37	2.94	2.37
2.7	3.75	3.34	3.61
3	3.82	3.92	3.82
3.3	4.45	4.62	4.45
3.6	4.92	4.96	4.92
3.9	5.33	5.61	5.33
4.2	5.58	5.97	5.58
4.5	6.1	6.52	6.1
4.8	6.38	6.96	6.38
5.1	6.78	7.54	6.78
5.4	7.32	8.18	7.3
5.7	7.87	8.92	7.85
6	8.6	9.78	8.49

ULTIMATE LOAD-5.7 TON

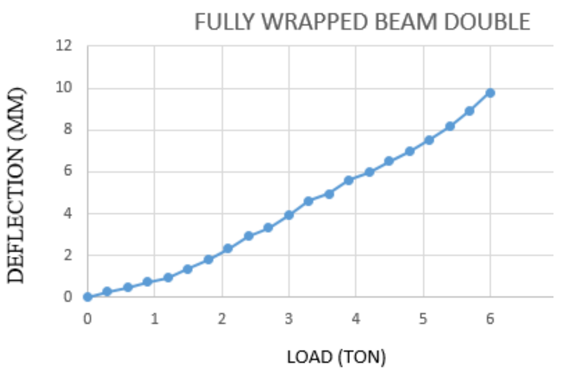

Fig. 10 deflection at mid span of FWB (Double)

Table VIII Load Mid-span deflection – FWB (Triple)

Load	Left	Mid	Right
0	0	0	0
0.3	0.1	0	0.1
0.6	0.3	0.25	0.3
0.9	0.4	0.46	0.4
1.2	0.5	0.6	0.5
1.5	0.53	0.85	0.53
1.8	0.56	1.18	0.56
2.1	0.61	1.56	0.61
2.4	0.71	2.03	0.71
2.7	1.12	2.56	1.12
3	1.46	2.96	1.46
3.3	1.88	3.5	1.88

Load	Left	Mid	Right
3.6	2.23	3.96	2.23
3.9	2.64	4.58	2.64
4.2	2.98	5.05	2.98
4.5	3.41	5.62	3.41

ULTIMATE LOAD- 6.3 TON

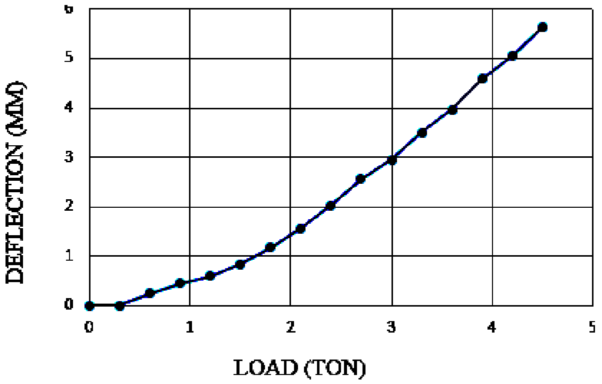

Fig. 10 deflection at mid span of FWB (Triple)

TableIX Load Mid-span deflection – MFWB (Single)

Load	Left	Mid	Right
0	0	0	0
0.3	0.07	0.2	0.06
0.6	0.25	0.56	0.26
0.9	0.3	0.62	0.31
1.2	0.48	0.82	0.49
1.5	0.82	1.3	0.80
1.8	1.2	1.72	1.18
2.1	1.65	2.3	1.6
2.4	1.9	2.7	1.89
2.7	2.3	3.24	2.35
3	2.6	3.63	2.62
3.3	3.1	4.13	3
3.6	3.3	4.61	3.31
3.9	3.7	5.06	3.76
4.2	4.18	5.562	4.19
4.5	4.6	6.07	4.51
4.8	5	6.73	5.2
5.1	5.5	7.38	5.6
5.4	6.45	7.92	6.42
5.7	6.48	8.63	6.48
6	7.35	9.73	7.35

ULTIMATE LOAD-5.7 TON

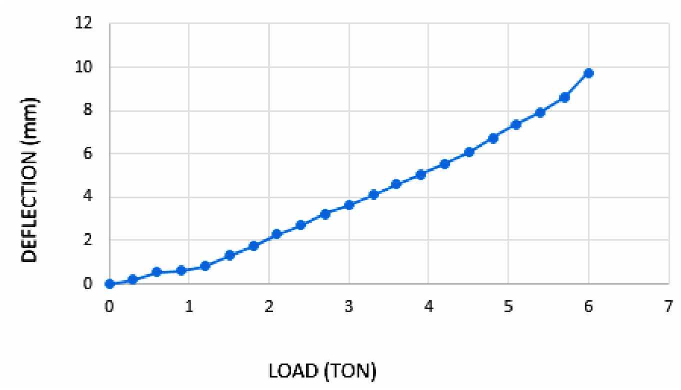

Fig. 10 deflection at mid span of MFWB (Single)

TableX Load Mid-span deflection – MFWB (Double)

Load	Left	Mid	Right
0	0	0	0
0.3	0.34	0.32	0.32
0.6	0.42	0.44	0.45
0.9	0.61	0.63	0.6
1.2	0.84	0.94	0.83
1.5	1.11	1.26	1.05
1.8	1.36	1.7	1.35
2.1	1.66	2.16	1.65
2.4	2.14	2.68	2.08
2.7	2.44	3.21	2.45
3	2.93	3.82	2.92
3.3	3.4	4.42	3.37
3.6	3.74	4.81	3.73
3.9	4.21	5.44	4.22
4.2	4.78	6.06	4.73
4.5	5.12	6.52	5.12
4.8	5.96	7.66	5.77

ULTIMATE LOAD-6.0 TON

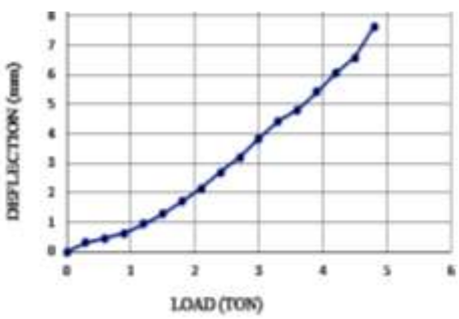

Fig. 11 deflection at mid span of MFWB (Double)

Table XI Load Mid-span deflection – MFWB (Triple)

Load	Left	Mid	Right
0	0	0	0
0.3	0.32	0.3	0.32
0.6	0.61	0.57	0.61
0.9	0.81	0.75	0.81
1.2	1.26	1.1	1.21
1.5	1.46	1.42	1.46
1.8	1.75	1.7	1.75
2.1	2.22	2.3	2.22
2.4	2.52	2.63	2.52
2.7	2.85	2.95	2.79
3	3.2	3.48	3.2
3.3	3.48	3.81	3.48
3.6	3.9	4.26	3.87
3.9	4.29	4.73	4.29
4.2	4.72	5.32	4.72
4.5	5.1	5.67	4.97
4.8	5.21	6.06	5.21

ULTIMATE LOAD- 6.6 TON

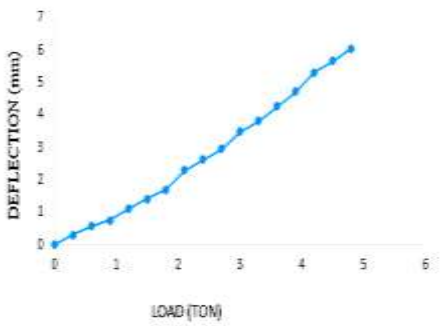

Fig. 12 deflection at mid span of MFWB (Triple)

Conclusion

The objective of this research which is to investigate deflection of CFRP strengthened beams under flexural loading has been achieved. As expected, the samples can support the more load, even though the CFRP laminates damage.

From this study some conclusions can be made:

1. The use of CFRP as a material wrapping for concrete can perform intended function to strengthen the concrete in tension zone.
2. CFRP reinforced concrete is good at supporting and resisting flexural loading.
3. The bond between concrete and CFRP played the main role in strengthening the concrete.
4. The performance and behaviour of CFRP reinforced concrete beam is comparable to the conventional steel reinforced concrete beam.

Based on the analysed result, some recommendations were made for further study:

1. To evaluate the flexural behavior of the samples, using the available deflection data.
2. To design the CFRP wrapped concrete beam with mechanical clamp is to be analysed.

3. To study the durability of CFRP wrapped concrete due to extreme condition such as exposed to concrete's alkaline environment, coastal environment, or submerge in sea-water.
4. To determine suitable safety factors for CFRP retrofitting.

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