Aspects of behavior of CFRP Sheet Wrapping Reinforced Concrete Beams

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Abstract - *It is common observation that structures are not able to give service as much as they are expected as per design due to rupture of the concrete and reinforcement caused by environmental factors or due to increase in applied load and many other causes. This paper studies the suitability of Carbon Fiber Reinforced Polymer (CFRP) sheets in strengthening of normal RC beam, Fly ash and GGBS used RC beam under flexure.*

An experimental result studies the Load-Deflection analysis and flexural strength of RC beam and CFRP rebounding of beams with CFRP sheets wrapping. Total 27 beam (150 X 150 X 700 mm) specimens of M-25 grade concrete were casted. To study the behavior of normal design of RC beam, Fly ash- GGBS used beams and Fly ash used beams. To study the behavior of normal design of RC beam and Fly ash- GGBS used beams when strengthened with CFRP sheet Bottom wrapping and CFRP sheet wrapping to three sides of beam.

Key Words: **CFRP, Fly ash, GGBS.**

1 INTRODUCTION

1.1 Strengthening of Structure

The structure, which is deficient in original design, can be retrofitted by strengthening of the structure. This strengthening can be achieved either by adding new lateral load resisting members or by strengthening the existing member. This is the most common and feasible alternative for seismic strengthening and a large number of techniques based on conventional strengthening methods, such as, RC jacketing, steel jacketing, as well as, based on advance materials such as FRP have been developed.

FRP system can effectively used for RC beam-column joint of building, bridge, etc. for retrofitting. Appropriately retrofitting of FRP composites significantly improved the lateral strength as well as ductility of the beam-column joint. Retrofitting with adhesive bonded FRP has been established around the world as an effective method applicable to mar types of concrete structural elements such as columns, beams, slabs and walls. Glass fiber, carbon fiber, aramid, ultra high molecular weight polyethylene, polypropylene, polyester and nylon this are the types of FRP. The change in properties of these fibers is due to the raw materials and the temperature at which the fiber is formed. In this research work CFRP sheet has used to strengthen structures such as column, beams, walls, slabs etc. The use of Carbon Fiber Reinforced Polymer (CFRP) sheet may classified as flexural strengthening, improving the ductility of compression members and shear strengthening.

In this experimental research work 27 reinforced concrete beams are casted using concrete of grade M25 grade. This research is mainly focus on CFRP sheets wrapping on the normal reinforced concrete beams and fly ash-GGBS used beams.

2. METHODOLOGY

The existing literature on use of CFRP as a retrofit material for strengthening of different structural components with special emphasis on fly ash-GGBS used concrete and fly ash used concrete beams was reviewed.

A mix design of M25 grade concrete will adopt to cast the beams in accordance with the IS: 10262-2009. First, the trial cubes will cast and then test after 28 days curing to determine their respective strength. From the results of compressive strength of cubes the final mix design will adopt.

A total of 27 Reinforced beams will cast with final mix proportion. Out of 27 beams 9 beams are without CFRP sheets, 9 beams are CFRP wrapping CFRP wrapping on 3 sides of beam and 9 beams are bottom CFRP wrapping. All beams will test for flexural loading.

Experimental program will carried out in two phases. First phase of experiment will to determine the compressive strength of the cubes for trial concrete mixes, and the second phase of experiment will to determine the flexural strength of control beams and then check the enhanced strength of the beam after strengthening them with varying CFRP.

Table 2.1 Replacement Levels for GGBS-Fly ash Used Concrete

Sr. No.	GGBS (%)	Fly ash (%)	Cement (%)
1	00	00	100
2	15	15	70
3	30	30	40

3. EXPERIMENTAL WORK

3.1. Material Used

Fly ash: Fly ash from Parli Vaijnath thermal power station has been used as partial replacement material for cement. Fly ash is fine material and possesses good pozzolanic property. The use of fly ash reduces availability of free limes and permeability thus results in corrosion prevention. When fly ash is used as part of cementitious material, quantum of heat liberated is low and staggers through pozzolanic reactions and thus reduces micro- cracking and improves soundness of concrete mass

Ground Granulated Blast Furnace Slag (GGBS): GGBS is obtained from Vaijnath Traders, Ambajogai. It is a by- product from the blast-furnaces used to make iron. GGBS has also been used as partial replacement to the cement.

Epoxy Resin: It is obtained from Vaijnath Traders, Ambajogai. Araldite Epoxy and Hardener were used for fill the minor cracks of the beam specimen and also used for strengthening scheme of an experimental work.

Table 3.1 Properties of Epoxy Resin

1	Viscosity	500-800
2	Colour	Transparent
3	Curing Time	60-80 min
4	Elongation	1% - 8.5%
5	Application	Bonding old to new concrete civil application

Carbon Fiber Reinforced Polymer (CFRP) Sheet: CFRP sheets obtained from Harshada Composite Solutions LLP, Nashik. Carbon FRP is electrically conductive and, therefore might give galvanic corrosion in direct contact with steel. Carbon fibers have a high modulus of elasticity, 200-800 GPa. The ultimate elongation is 0.3-2.5 % where the lower elongation corresponds to the higher stiffness and vice versa. Carbon fibers do not absorb water and are resistant to many chemical solutions.

Steel: Steel is obtained from Vaijnath Traders, Ambajogai. Steel reinforcement is confirming to IS: 432-1982. Minimum Carbon content in steel is 0.3% and Yield strength of steel is 500Mpa.

3.2. Experimental Set Up

Concrete Mix Design: Concrete Mix Design for M-25 Grade of Concrete is designed by using IS 10262-2019 Code Method.

Table 3.2 Mix proportion for M25 grade of concrete

Cement	Fine Aggregate	Coarse Aggregate	Water
372.00 kg/m^3	703.52 kg/m^3	1251.41 kg/m^3	186.00 kg/m^3
1.00	1.89	3.36	0.50

Compressive strength test for selected concrete mix design: There are 6 cubes of size 150mm x 150mm x 150mm casted in standard moulds and cured for 28 days. After 28 days curing these cubes are tested on Compressive Testing Machine and failure load was recorded. The test results are satisfying the targeted strength, so the selected concrete mix proportion is adopted for all specimens.

Table 3.3 Test result for compressive strength of concrete cubes.

Sr. No.	Mix Proportion	Compressive strength (7 Days) N/mm^2	Average Compressive strength (7 Days) N/mm^2	Compressive strength (28 Days) N/mm^2	Average Compressive strength (28 Days) N/mm^2
1	1:1.89 :3.36	18.67	18.81	29.77	30.36
		19.11		30.66	
		18.67		30.66	

Figure 3.1 Testing of concrete cubes at NHCE Concrete Technology lab.

Beam specimen preparation: An experimental work was conducted to investigate the behavior of CFRP (Carbon Fiber Reinforced Polymer) wrapping reinforced concrete beams. Total 27 reinforced concrete beams were casted that were reinforced with minimum conventional longitudinal and transverse steel as per the IS 456: 2016 provision. The beam specimens consisted of size 150mm x 150mm x 700mm.

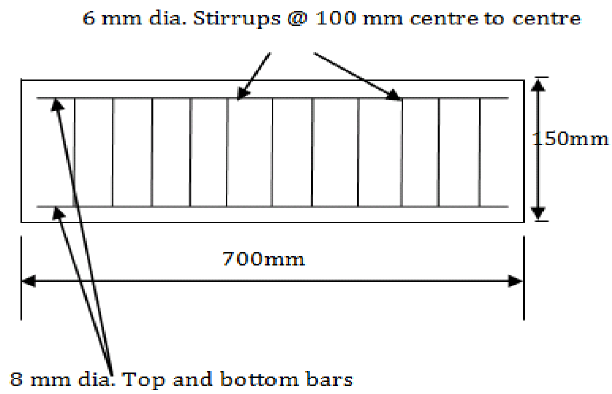


Figure 3.2 Longitudinal section of beam.

4. RESULTS & DISCUSIONS

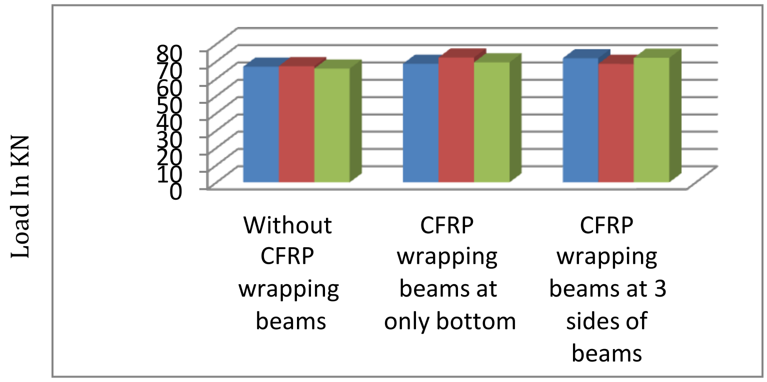
The beams are tested near their failure strength. The CFRP wrapped beams were tested for their ultimate strength. Normal RC beam, Fly ash used RC beam and Fly ash- GGBS used beams are tested up to failure. The load deflection data obtained from experimental tests are shown in following tables.

Table 4.1 Test results for load – deflection analysis of normal RC beams

Sr. No.	Mix Proportion	Normal Failure Condition			Ultimate Failure Condition		
		Load (KN)	Deflection (mm)	Average Load (KN)	Load (KN)	Deflection (mm)	Average Load (KN)
Normal reinforced concrete beams without CFRP wrapping							
01	1:1.89: 3.36	54.60	4.90	54.03	66.90	6.30	66.63
02	1:1.89: 3.36	55.10	4.34		67.20	6.63	
03	1:1.89: 3.36	51.40	3.85		65.80	5.29	
Normal reinforced concrete beams with Bottom CFRP wrapping							
04	1:1.89: 3.36	49.90	3.90	54.43	68.60	6.47	70.06
05	1:1.89: 3.36	55.60	5.34		72.20	7.25	
06	1:1.89: 3.36	57.80	5.29		69.40	6.90	
Normal reinforced concrete beams with CFRP wrapping to three sides of beam							

07	1:1.89:3.36	57.40	5.33	57.23	71.80	6.90	70.77
08	1:1.89:3.36	55.80	4.81		68.50	6.47	
09	1:1.89:3.36	58.50	5.47		72.00	7.16	

The beam is tested up to failure. The ultimate load of specimen is noted and also the load (normal failure load) is noted when normal crack develops in the beam specimen. The normal failure load, ultimate load and deflection are given in Table 4.1.



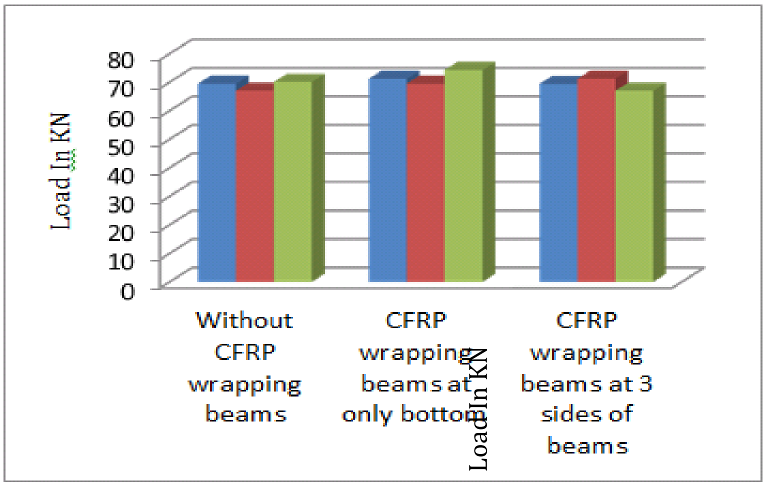
Graph 4.1 Load Carrying by Normal reinforced concrete beams.

Table 4.2 Test results for load – deflection analysis of Fly ash and GGBS using RC beams (Cement replaced with 15% fly ash and 15% GGBS)

Sr. No.	Mix Proportion	Normal Failure Condition			Ultimate Failure Condition		
		Load (KN)	Deflection (mm)	Average Load (KN)	Load (KN)	Deflection (mm)	Average Load (KN)
Fly ash and GGBS used RC beams without CFRP wrapping							
01	1:1.89:3.36	53.20	3.91	54.77	69.50	6.42	68.87
02	1:1.89:3.36	53.90	4.15		67.00	6.18	
03	1:1.89:3.36	57.20	5.33		70.10	6.77	
Fly ash and GGBS used RC beams with Bottom CFRP wrapping							
04	1:1.89:3.36	55.90	4.58	55.70	69.40	6.35	69.20
05	1:1.89:3.36	54.30	3.72		71.20	6.32	
06	1:1.89:3.36	56.90	4.42		67.00	6.81	
Fly ash and GGBS used RC beams with CFRP wrapping to three sides of beam							

07	1:1.89:3.36	59.70	4.27	55.33	71.20	6.67	71.67
08	1:1.89:3.36	54.40	3.98		69.50	6.24	
09	1:1.89:3.36	51.90	4.03		74.30	5.93	

The beam is tested up to normal failure. The load (normal failure load) is noted when normal crack develops in the beam specimen. Then CFRP sheet is wrapped on the beam at the bottom and 3 sides of the beam excluding top side. After 3 days curing the beam specimen is tested up to failure and the ultimate load is noted. The normal failure load, ultimate load and deflection are given in Table 4.2.



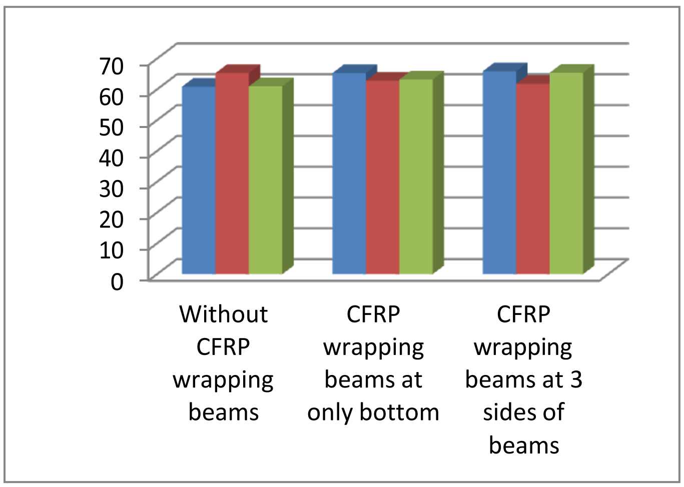
Graph 4.2 Load Carrying by Fly ash and GGBS using RC beams (Cement replaced with 15% fly ash and 15% GGBS).

Table 4.3 Test results for load – deflection analysis of Fly ash and GGBS using RC beams (Cement replaced with 30% fly ash and 30% GGBS)

Sr. No.	Mix Proportion	Normal Failure Condition			Ultimate Failure Condition		
		Load (KN)	Deflection (mm)	Average Load (KN)	Load (KN)	Deflection (mm)	Average Load (KN)
Fly ash and GGBS used RC beams without CFRP wrapping							
01	1:1.89:3.36	47.90	3.86	49.17	60.90	5.49	62.00
02	1:1.89:3.36	49.00	3.90		65.30	6.04	
03	1:1.89:3.36	50.60	4.32		61.00	5.87	
Fly ash and GGBS used RC beams with Bottom CFRP wrapping							
04	1:1.89:3.36	50.10	3.65	49.94	65.30	6.31	63.77
05	1:1.89:3.36	48.40	3.49		62.80	6.00	

06	1:1.89:3.36	51.30	4.15		63.20	6.05	
Fly ash and GGBS used RC beams with CFRP wrapping to three sides of beam							
07	1:1.89:3.36	49.70	3.75	49.37	65.90	6.17	64.37
08	1:1.89:3.36	48.60	3.37		61.80	5.81	
09	1:1.89:3.36	49.80	3.52		65.40	5.94	

The beam is tested up to normal failure. The load (normal failure load) is noted when normal crack develops in the beam specimen. Then CFRP sheet is wrapped on the beam t the bottom and 3 sides of the beam excluding top side. After 3 days curing the beam specimen is tested up to failure and the ultimate load is noted. The normal failure load, ultimate load and deflection are given in Table 4.3.



Graph 4.3 Load Carrying by Fly ash and GGBS used RC beams (Cement replaced with 30% fly ash and 30% GGBS).

5. CONCLUSIONS

1. The ultimate load carrying capacity of normal RC beams with bottom CFRP wrapping is 5.15% greater than normal RC beams without CFRP wrapping and the deflection is also more. This shows that the beam strengthen with CFRP wrapping gives more strength to the beams.

2. The ultimate load carrying capacity of normal RC beams with CFRP wrapping at 3 sides of the beam is 6.21% greater than normal RC beams without CFRP wrapping and the deflection is also more. This shows that the beam strengthen with CFRP wrapping gives more strength to the beams.

3. CFRP wrapping to 3 sides of the beam takes more load than bottom CFRP wrapping and without CFRP wrapping.

4. Deflection of CFRP sheet wrapping beams is more than beams without wrapping.

5. The ultimate load carrying capacity of 15% fly ash of cement and 15% GGBS of cement used RC beams with bottom CFRP wrapping is 0.48% greater than 15% fly ash of cement and 15% GGBS of cement used RC beams without CFRP wrapping and the deflection is also more.

6. The ultimate load carrying capacity of 15% fly ash of cement and 15% GGBS of cement used RC beams with CFRP wrapping at 3 sides of the beam is 4.07% greater than normal RC beams without CFRP wrapping, but the deflection is less.

7. The ultimate load carrying capacity of 30% fly ash of cement and 30% GGBS of cement used RC beams with bottom CFRP wrapping is 2.85% greater than 30% fly ash of cement and 30% GGBS of cement used RC beams without CFRP wrapping and the deflection is also more.

8. The ultimate load carrying capacity of 30% fly ash of cement and 30% GGBS of cement used RC beams with CFRP wrapping at 3 sides of the beam is 3.82% greater than 30% fly ash of cement and 30% GGBS of cement used RC beams without CFRP wrapping, but the deflection is less.

9. GGBS-fly ash used beams (Cement replaced with 30% fly ash and 30% GGBS) has less load carrying capacity as compared to normal reinforced concrete beams and GGBS-fly ash used beams (Cement replaced with 15% fly ash and 15% GGBS).

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