Response of Reinforced Concrete Beams Retrofitted By Carbon Fiber

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Abstract - *The purpose of this experimental work is to study investigate and formulate the behavior of reinforced concrete beams before and after retrofitting by Carbon Fiber to increase the strength of deteriorated beams. The investigations were carried out on flexural behavior of concrete beams with concrete grade M15, M25 & M35. The Fifteen nos. of Reinforced Concrete (RC) beams were casted of size 150 X 150 X 700 mm. Materials used for rehabilitation of beams i.e. Carbon Fiber, were initially stressed to 60% & 90% of ultimate strength of Control Beam. The experimental results indicated that the rehabilitation technique of RC beams by using Carbon Fiber will increase the ultimate strength of beams to order of 30%. The average increase in strength of beam by Carbon Fiber is more than that of control beam. The deflection considerably increases after retrofitting at 60% and 90% stressed levels by Carbon Fiber it increases 19% of respective stressed level. Hence we noted that the load carrying capacity of RC beams by using considerably more than Carbon Fiber.*

***Key Words*: Carbon Fiber, Rehabilitation, Retrofitting, Shear, Strengthening, Preloading.**

1. INTRODUCTION

Reinforced concrete structural components are found to exhibit distress, even before their service period is over due to several causes. Such unserviceable structures require immediate attention, enquiry into the cause of distress and suitable remedial measures, so as to bring the structures back to their functional use again. This strengthening and enhancement of the performance of such deficient structural elements in a structure or a structure as a whole is referred to as retrofitting.

1.1 Rehabilitation:

It is process of restore a original building up to certain predetermine strength considering with new requirements of building with a view of original element strength, life, service condition of structure and construction materials.

1.2 Retrofitting

It is process of restore a original building up to certain predetermine strength considering with new requirements of building with a view of original element strength, life, service condition of structure and construction materials.

1.3 Fiber Reinforcement Composites (FRC)

The composite can be defined as the two or more dissimilar materials which when combined are stronger than the individual material. Composites can be both natural and synthetic (or manmade) and as material technology move toward more sustainable solutions, the focus on the use of organic, or natural materials, especially as reinforcement.

2. EXPERIMENTAL PROGRAMME

2.1 Introduction

In the existing scenario there are a number of laminates like CFRP (Carbon Fiber reinforced polymer), GFRP (Glass Fiber reinforced polymer) with cement mortar etc. are being used for retrofitting of structures. Thus in the present study shear

deficient beams are cast and subsequently stressed to 60%, 90% of the safe load and are retrofitted and bonded to beam with cement slurry and having Glass Fiber and carbon Fiber sheets to the longitudinal axis of the beam.
For the proposed work thirty no. of beams of size (150 x 150 x 700 mm) beams were cast. Out of these two each are controlled beams tested to find out safe load carrying capacity of beams of the 24 beams are stressed to 60% and 90% of the safe load and then retrofitted with Glass Fiber and carbon Fiber laminate.

2.2 Problem Statement

Reinforced concrete structural components are found to exhibit distress, even before their service period is over due to several causes. So we strengthen the distress member by retrofitting it with Carbon Fiber.

2.3 Test Programme

The test program is so devised so as to find out the properties of materials to be used for casting of beams and then the behavior of retrofitted beams. The test program consists of:
1. Determination of basic properties of constituent materials namely cement, sand, coarse aggregates and steel bars as per relevant Indian standard specifications.
2. Casting of Fifteen beams of size (150 x 150 x 700mm) using M15, M25 and M35 grade of concrete, the mix of which is designed as per Indian Standards.
3. Computation of the ultimate failure load of the beams and subsequently the safe load from deflection criteria.

3 MATERIALS USED TO FABRICATE THE SPECIMENS

Cement, fine aggregates, coarse aggregates, reinforcing bars are used in designing and casting of beams. The specifications and properties of these materials are as under:

3.1 Cement

Portland pozzolana 53 grade cement used for the study. The physical properties of cement as obtained from various tests are listed in all the tests are carried out in accordance with procedure laid down in IS: 8112-1989.

3.2 Fine & Coarse Aggregates

Locally available sand is used as fine aggregate in the cement mortar and concrete mix. The physical properties and sieve analysis of results of sand.
Crushed stone aggregate (locally available) of 20mm and 10mm are used throughout the experimental study. The physical properties and sieve analysis of results of both coarse aggregate.

Table 1: Physical Properties of Aggregates

Sr.No	Characteristics	Value	Value
1	Specific gravity	2.56	2.65
2	Bulk density loose	1.48	-
3	Fineness modulus	2.51	6.47
4	Water Absorption	2.06%	3.645%
5	Grading Zone	Zone III	Zone II

3.3 Water

The quality of mixing water for mortar has a visual effect on the resulting hardened cement mortar. Impurities in water may interfere with setting of cement & will adversely affect the strength of cause staining of its surface & may also lead to its corrosion. Usually water that is piped from the public supplies is regarded as satisfactory.

3.4 Reinforcing Steel

HYSD steel of grade Fe-500 of 10mm, 8mmand 6mm diameters were used as longitudinal steel. 10mm diameter bars are used as tension reinforcement and 8mm bars are used as compression steel. 6mm diameter bars are used as shear stirrups.

Table 2: Properties of Reinforcing Steel

Bar Size	Yield Stress (MPa)	Yield Strain	Ultimate Strength (MPa)	Ultimate Strain
Φ10mm	485	0.0025	590	0.0305
Φ8mm	472	0.0027	560	0.0315
Φ6mm	465	0.0029	528	0.0326

3.5 Carbon Fiber

Carbon fiber is composed of carbon atoms bonded together to form a long chain. The fibers are extremely stiff, strong, and light, and are used in many processes to create excellent building materials. Carbon fiber material comes in a variety of "raw" building-blocks, including yarns, uni-directional, weaves, braids, and several others, which are in turn used to create composite parts.

3.6 Concrete Mix: (As per IS 10262-2009 & MORT&H)
Mix Proportions for One cum of Concrete

Description	M15	M25	M35
Mass of Cement(kg/m^{3})	270	320	400
Mass of Water (kg/m^{3})	135	138	160
Mass of Fine Agg.(kg/m^{3})	711	751	704
Mass of Coarse Agg. (kg/m^{3})	1460	1356	1271
Mass of 20 mm (kg/m^{3})	1051	977	915
Mass of 10 mm (kg/m^{3})	409	380	356
Water Cement Ratio	0.5	0.43	0.4
Mass of Admixture	nil	nil	nil

3.7 MORTAR MIX:

The range of mix proportion recommended for common ferrocement application are between 1:1.5 to 1:2.5 (cement: sand) by weight, but not greater than 1:3 and water Cement ratio by weight, 0.35 to 0.5. The higher the sand content higher is the required water contents to maintain same workability. In the present study the proportion of cement – sand mortar used for the cement is 1:2 (cement: sand and the water-cement ratio) for mortar taken as 0.40.

4 SPECIMEN DESCRIPTION

In the present study a total of (15) R.C. beams are cast and cured under laboratory conditions. We are design using M15, M25, M35 grade concrete and Fe 500 steel. The RCC beam is designed using limit state method considering it to be an under reinforced section. The beam is designed having 2 steel bars of 8mm dia. at compression face and 2 bars of 10mm dia. at tension face. The stirrups used are of 6mm diameter and at the spacing of 125 mm which is more than the minimum required spacing, so that the beam should behave as a shear deficient beam. Longitudinal section and cross-section of beam is shown in Figure below

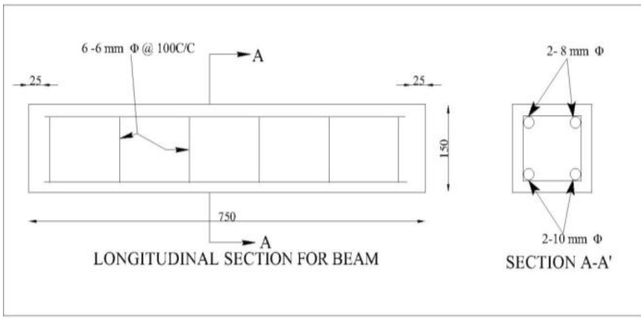


Fig No 1. Cross section of specimen

5 SPECIMEN IDENTIFICATION AND FABRICATION OF THE TEST SPECIMENS

The casting of beams is done in a single stage. We were casting fifteen beams of size 150 x150x700 mm. First of all the entire beam mould is oiled. So that the beam can be easily removed from the mould after the desired period. Spacers of size 25 mm are used to provide uniform cover to the reinforcement. When the bars have been placed in position as per the design, concrete mix is poured in the mould and vibrations are given with the help of table vibrator. The vibration is done until the mould is completely filled and there is no voids left. The beams are then removed from the mould after 48 hours. After demoulding the beams are cured for 28days using plastic water tank.

6 INSTRUMENTATION AND TEST SETUP

All the Fifteen beams are tested under simply supported end conditions. Single point loading is adopted for testing and spacing between single concentrated loads is so selected that l/d ratio for the beam to be failing in combined shear and flexure. The testing of beams is done with the help of hydraulically operated machine connected to load cell. The load is applied to the beam with the help of universal testing machine and the data is recorded from the data acquisition system, which is attached with the load cell. Out of these 10 beams of each grade (M15,M25,M35) 2 are control beam, which were tested after 28 days of curing to find out the safe load which is taken as load corresponding to deflection of L/250 i.e. 3 mm. Four each of the remaining 8 beams are stressed up to 60% and 90% of the safe load.

Photo.1: Test setup and instrumentation of beam

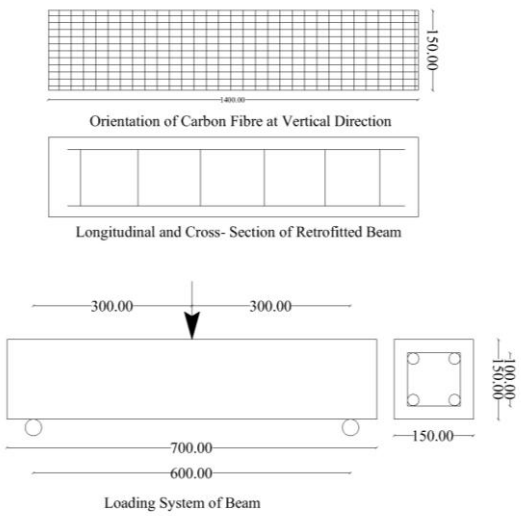


Fig 2. Geometry and cross section laboratory specimens

6.1 Retrofitting of Beams

The beams are stressed up to a specified limit as above and then retrofitted by applying glass fiber mesh and carbon fiber mesh and then plastering it with cement mortar up to the thickness of 10mm for all 8 beams of each grade. Therefore final cross section of beam with plaster will become 170 x 170 x 700 mm. Effect of two different stress levels of 60%and 90% has been studied to see their effect on the strength of retrofitted beams with rectangular glass fiber and carbon fiber sheet. Placing it over the all four longitudinal surfaces of beam. An overlap of 3 inches at the place of joint between mesh is introduced.

7 REHABILITATION AND RETROFITTING OF REINFORCED CONCRETE BEAMS

By using two types of fiber sheets are used:

7.1 Procedure of Applying CARBON FIBER SHEET:

1. Repairs and Structural Preparation: Basic repairs must be made to the structure prior to strengthening with FRP spelled an unsound concrete removed, Corroded and damaged steel to be treated rust converting primer and protective coating.

2. Surface Preparation: The surface preparation to be repaired is typically rubbed off to smooth out irregularities, Remove contaminants and radius shaft corners. This can be performed in one time.

3. Putty: Adhesive high viscosity putty is applied when necessary to the surface to fill in "Bug Holes" offsets or voids

4. Primer Coat: In order to promote adhesion and prevent the surface from driving resin from the FRP, or low viscosity epoxy primer is applied with a roller.

5. Cutting Fabrics: The fabric is carefully measured and cut in accordance.

6. Saturating Fabric: On large, high volume projects, the fabric can be saturated using custom saturator. For lower volumes and shorter strips, the fabric can be either saturated on a Table, or the surface can be coated with resin and the dry fabric applied.

7. Applying Fabric: The prevented, or dry, fabric is carefully laid on to the surface and smooth out to remove air bubbles.

8. Quality Control: During the cure, 24 hours depending on ambient condition the fabric is checked to ensure that all air bubbles are removed.

9. Second Saturant Coat: After inspection of wrapped fiber apply second coat of Saturant on wrap and apply subsequent FRP layer as per design apply coarse river sand if wrapping is followed by plastering.

Table 3: Properties of Carbon Fiber and Saturant

I- CARBON FIBER			
Sr.No.	**Particular**	**Test Method Code**	**Test Result**
1	Tensile Strength	ASTM D 2243-85	3.8 Gpa
2	Tensile Modulus	ASTM D 2243-85	240 Gpa
3	Ultimate Elont^n	ASTM D 2243-85	1.70%
4	Density	ASTM D 3317	1.74gm/m^3
5	Weight per sq m	D 579-89	419gm/ m^2
II- Epoxy Resin			
1	Viscosity at 27 C	Base resin	10000-15000 Mpa
		Hardener	100-600 Mpa
2	Density	Base resin	1.1 g/cc
		Hardener	0.88 -0.98 g/cc

8 RESULT AND DISCUSION

8.1 Introduction

Firstly control beams were tested to failure and the data corresponding to it is recorded through data acquisition system. Then two beams of per grade (M15, M25, and M35) of the remaining of the six beams are ultimate load of control beam. The safe load is calculated from the load corresponding loads at 60%, 90% stress level are 24 beams (M15, M25, and M35). The beam designations as used are as follows:

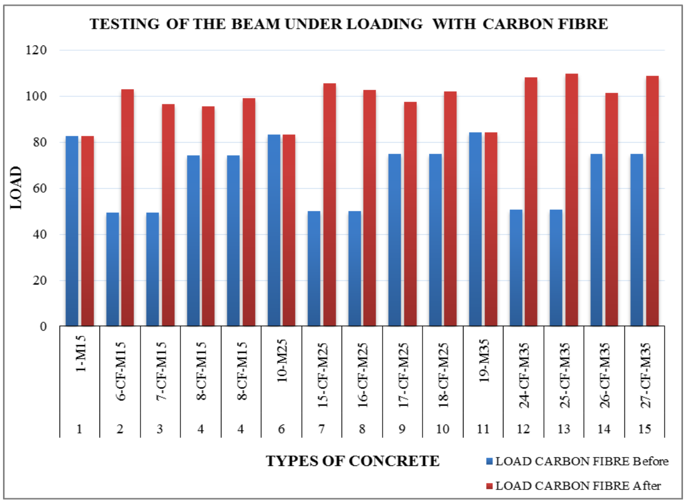
Table 4: The beam designations for M15, M25, and M35

Description	Grade		
Control Specimen	**M 15**	**M 25**	**M35**
Retrofitted Beam CF-60 %	R1	R5	R09
Retrofitted Beam CF-60 %	R2	R6	R10
Retrofitted Beam CF-90 %	R3	R7	R11
Retrofitted Beam CF-90 %	R4	R8	R12

Two beams are tested as a control beam under single concentrated point loading system. As the beams are deficient in shear, so the distance between one loads is so selected that L/d ratio is for the beam to be failing either in shear or flexure or in both. The load is increased in intervals and deflection is noted at L/2 and L/4.In the beginning the deflection in middle increases almost.

Table 5: Testing Of the Beam under Loading (CF)

Sr. No.	Type of Concrete	LOAD	
		CARBON FIBER	
		Before	After
1	1-M15	82.45	82.45
2	2-CF-M15	49.47	102.8
3	3CF-M15	49.47	96.6
4	4-CF-M15	74.205	95.46
5	5-CF-M15	74.205	105.6
6	6-M25	83.19	83.19
7	7-CF-M25	49.914	105.5
8	8-CF-M25	49.914	102.625
9	9-CF-M25	74.871	97.55
10	10-CF-M25	74.871	102.102
11	11-M35	84.35	84.35
12	12-CF-M35	50.61	108.25
13	13-CF-M35	50.61	109.8
14	14-CF-M35	75.015	101.263
15	15-CF-M35	75.015	108.6



Graph 1: Testing of the Beam under Loading (C.F)

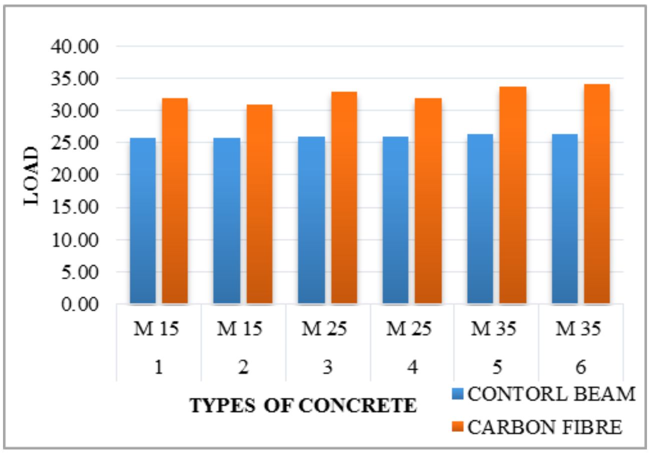
8.2 Comparisons of Retrofitted (<u>CARBON FIBER</u>) and Controlled Beam

8.2.1 Comparison of retrofitted Carbon Fiber beam with Control beam:

Retrofitting by Carbon fiber will increase ultimate load of the order of 40 % and safe load corresponding to a deflection of 15 mm increased by 21 %.

Table 6: Comparison of Control Beam and Carbon Fiber (60 % stressed)

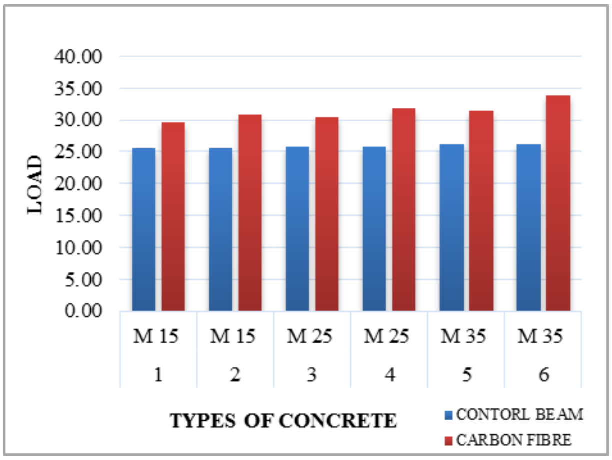
Sr. No.	Type of Concrete	Control Beam	Carbon Fiber	Percentage Increase
1	M 15	25.65	31.98	24.68
2	M 15	25.65	30.99	20.83
3	M 25	25.88	32.82	26.82
4	M 25	25.88	31.93	23.36
5	M 35	26.24	33.68	28.33
6	M 35	26.24	34.16	30.17



Graph 2: Flexural strength of Control beam and Carbon fiber (60 % stressed)

Table 7: Comparison of Control Beam and Carbon Fiber (90 % stressed)

Sr. No.	Type of Concrete	Control Beam	Carbon Fiber	Percentage Increase
1	M 15	25.65	29.70	15.78
2	M 15	25.65	30.86	20.30
3	M 25	25.88	30.35	17.26
4	M 25	25.88	31.77	22.73
5	M 35	26.24	31.50	20.05
6	M 35	26.24	33.79	28.75



Graph 3: Flexural strength of Control beam and Carbon fiber (90 % stressed)

9 CONCLUSIONS

Carbon Fibers for retrofitting has been proven itself to be a better feasible option than other methods. So the future prospect for the utilization of Carbon Fiber as well as Glass Fiber in civil engineering infrastructure are good research around the world are now looking at the new and innovative ways of utilization of same.

Based upon the tested results of experimental study undertaken the following conclusions may be drawn:

- The rehabilitation technique of RC beams by using Carbon Fibers system is applied and can increase the ultimate load from (35 to 45%) respectively compared to the control beams
- The ultimate load carrying capacity of RC beams after retrofitting with carbon Fiber is more. But the part of deflection, the deflection of RC beams is more.
- But for carbon Fiber there was same crack pattern after retrofitting as before retrofitting.
- The application of carbon Fiber is easy with skilled labour but in case of unskilled labour.
- After retrofitting all the specimens of RC shown large deflection at the ultimate load and a significant change in ductility ration.
- As we Carbon Fiber is easy to use and also easy to apply and it gives better results than Carbon Fiber when we significantly change the wrapping pattern of it.
- When the load is given to the retrofitted beam the chances of sudden failure are more in Carbon Fiber.
- The failure of the composite is characterized by development of flexural cracks over the tension zone. The spacing of cracks is reduced for retrofitted beams indicating better distribution of stress.
- Carbon Fiber stressed with 60% after retrofitting the stressed beams has the highest load carrying capacity as compared to control beam as well as the other beams retrofitted with different stressed level.
- After retrofitting, all the test specimens shown large deflection at the ultimate load, and also a significant increase in the ductility ratio.

REFERENCES

1. Dr. Ragheed Fatehi Makki et: "Response of Reinforced Concrete Beams Retrofitted By Ferrocement."*International Journal Of Scientific & Technology Research Volume 3, Issue 9, September 2014 ISSN 2277-8616*
2. Mr. Sandesh.S.Patil.: Prof. R A Ogale.: Prof. Dr. Arun Kr. Dwivedi' et: "Performances of Chicken Mesh on Strength of Beams Retrofitted Using Ferrocement Jackets" *IOSR Journal of Engineering (IOSRJEN) ISSN: 2250-Fifteen21 Volume 2, Issue 7(July 2012), PP 01-10*
3. M. Veera Reddy and E. Maheshwar Reddy et: "Rehabilitation of Shear Deficient RC Beams" *International Journal of Earth Sciences and Engineering **1125** ISSN 0974-5904, Vol. 04, No. 06, December 2011, pp. 1125-1128*
4. Mr. Anshu Tomar : "Retrofitting Of Shear Deficient Rc Beams Using Ferrocement Laminate"
5. Sivagurunathan. Ba* and Vidivelli. aBb et: "Strengthening of Predamaged Reinforced Concrete Beams by Ferrocement Plates" *International Journal of Current Engineering and Technology ISSN 2277 – 4106*