COMPARATIVE ANALYSIS OF THE REINFORCED CONCRETE BEAM BY USING VARIOUS FORMS OF RETROFITING TECHNIQUES

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Abstract
The main objective of this study to increase the durability of beam by using the various types of jacketing techniques. In this research, I am considering the two methods for retrofitting the beams, i.e. the first method is Reinforced Concrete jacket (RC), other is carbon fiber reinforced polymer jacket (CFRP). In this study, 100 mm thickness of RC jacketing is used at all four sides of the beam while the CFRP with different thickness of sheet are used. After casting the beams, the point load test is done on loading frame machine and check the crack, ultimate strength in the beam and comparing the results and cost of all different types of retrofit techniques for reinforced concrete. The Analyses have also performed in ABAQUS software and then validation is done by comparing the deformation and stress behavior in ABAQUS and experimentally. The conclusion of this study shows that the RC jacketing strength increased by 63% where as in CFRP it increases by 48.5%. The test results show that the RC jacketing gain more strength then other jacketing methods and increase the flexural strength.
Key words: Beam, Reinforced Concrete jacket, Carbon Fiber, Reinforced, Polymer jacket.

1. INTRODUCTION

Although reinforced concrete structures are of high strength, but due to earthquakes and other effects such as wind loading, seismic loading and creeping, the structure collapses, deteriorates and loses its strength over time [1]. As the structure completes its service life, the load capacity of the structure also decreases. So the structure is being retrofitted using various jacketing methods. It may be appropriate to combine both local and global retrofit strategies under a feasible and economical retrofit scheme. The two types of strategies which retrofit is depending upon various failure occurs which as follows: -

Global Strategies

When a building faces multiple deficiency and damage due to earthquake, wind & lateral load impact it is important to have strength & lateral load resistant feature so that additional infill walls, shear walls, bracing enhances strength.

Local Strategies

Local strategies in beam, column, beam column joints in local strategies are retrofitted by jacketing that is steel, concrete or FRP and then comparisons are made to verify that is more appropriate for multi-storey construction.

But nowadays Jacket is the best way for strengthen the RC structure. There are three way of Jackets to strengthen our structures i.e. steel, RC, RCPC and Jacket with high Tension. The main aim of Jacketing is:

- It helps to increase the shear strength by Traverse Reinforcement.
- It helps to increase the shear capacity with help of stirrups by using fiber reinforcement in

corrode stirrups.

- It also increases the flexural strength by providing the longitudinal reinforcement.

2. REVIEW OF RECENT RESEARCH SECHDULE ARE PRESENTED BELOW:

Aobaidat et al., (2010): investigated the behavior of structure by using CFRP laminate of retrofitted beam in shear or flexure. In this paper the author considers the parameters like internal reinforcement and length of CFRP. The author tested the shear and flexure strength of beam by wrapping CFRP to regain or restore the strength which was greater than the strength of control beam. He found that the efficiency of strengthen beam by CFRP depends upon the length & the main failure occur due to plate debonding on retrofitted beam.

Kmohandas et al., (2016): observed the efficiency of GFRP (glass fiber reinforced polymer) under different loading conditions and reinforcement condition. The author casted a 16 beam and retrofit the beam by using a single layer of GFRP with various types of resin i.e. epoxy, GP and then check the it for flexural strength test. He found that the GFRP sheet increase the flexural strength and also found the compressive strength of single layer cube with GFRP which was greater than 15.14% then the normal compressive strength.

Sachin S. Raval et al., (2013): analyzed the effect of smooth and chipped surface of beam by comparing them. The author casted the total ten beams of size (150×300×2100) mm. He casted four beam with smooth surface connecting with dowel and bonding agents and used micro concrete and also casted four beam with chipped surface. After casting the two-point loading system was applied to check the failure mode and crack pattern. The author found that the surface with smooth and bonding agent and with micro concrete has better performance and the surface with chipped without micro concrete has better performance.

Alhadid and Youssef (2018): investigated the behavior of continuous beam for the non-linear behavior. He studied about the interfacial slip distribution and behavior of actual non-linear of concrete and steel. The researcher set the parameters like (beam depth and width and span length). The jacket applied only one sided of all soffit corners. After testing and analysis the beams he found that the strength increases where the jacket applied and he also found that the failure mode was ductile in nature because of crushing of concrete and tension in steel bars.

Hiroyuki Nakhara (2018): the author investigated the study of structural frame with concrete column and steel beams. The author used the steel jacket for his research work, he used steel tube and testing it for cyclic loading with different parameters and properties. The author found that strength increase slightly 5%-11% and also found that relation between story drift angle and bending moment which was reveal by self-centering behavior.

3. MATERIALS

Cement

Class 43 ordinary Portland cement (OPC) was used for building work with a specific gravity of 3.15. The mass density of cement is 29.48 kg/m3.

Sand

Crushed sand was used with a specific gravity of 2.64, where crushed sand was used for strong bonding strength. The bulk density is 1493.56 kg/m3 and the water absorption is 1%.

Coarse aggregate

The maximum size of aggregate of 10 mm having specific gravity 2.62 was used and grading of aggregate was zone II. The bulk density is 1476 kg/m^3 and the water absorption is 6%.

Carbon fiber

CFRP has a high power, longevity. It is used for high strength and rigidity of various thicknesses and the amount of layers used for retrofitting the beam.

Epoxy resin

Epoxy resin was used for strong bonding between the surface of the concrete and the carbon fiber sheets.

4. EXPERIMENTAL PROGRAMME

RC bar have been casted and tried under various stacking condition. Four shafts were casted of size 230×230×1500 mm, the range length of bar is 1500 mm and width are 230 mm. In this the bar are plan by utilizing limit state strategy and the solid evaluation of M40. The amount of materials is determined by utilizing the code that is blend plan particular BIS 10262:2009. The size of fortification is 4 number 12 mm measurement bar utilized in both pressure and strain part and grade was Fe 415. The stirrups size is 6 No's with 8 mm distance across of 250 mm community to focus separating [2][3]. The heap applied at focus as appeared in Figure 1. Previously pillar, two blocks were casted and tried for check the compressive is 39.5 N/mm^2.

4.1 Casting of RC beams

The beams were cast. The size of all specimens was identical and shape was square having dimensions 230×230×1500 mm. The rectangular reinforcement cage was also prepared as shown in Figure 1 and The rectangular wooden mould was prepared as shown in Figure 2. The mixing of concrete was done by using mix design specification BIS 10262:2009, after mixing beams were casted by proper alignment of reinforcement of size main bar was used 12 mm and shear reinforcement was 8 mm with 250 mm center to center spacing. The casted of beams were shown in Figure 2. After casting of beams, the first point load was applied on beam to check the crack load and ultimate load of all control beams. After testing, the all control beams were retrofitted by using RC jacketing, CFRP jacketing. CFRP used to increase the strength and it's also helps to protect the beam from corrosion [3,4]

Fig 1 Plywood moulds with Reinforcement cage **Fig 2 Casting of beams**

4.2 Retrofitting of beams

4.2.1 RC jacketing's.

Every one of the four sides of pillar were retrofit by utilizing RC jacketing. The 100 mm

jacketing utilized in every one of the four sides of pillars with support size 4 No's of 16 mm distance across bars and shear fortification size 6 no's 8 mm measurement bar 250 mm community to focus separating. The size of shaft become 430×430×1500 mm, the range length became 1500 mm and cross segment territory became 430×430 mm2 and solid evaluation M45 and steel grade 415 was utilized. Retrofitting of pillar was appeared in Figure 3 and recasting of beam in figure 4.

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Fig 3 Retrofitting of beam


Fig 4 Recasting of beam

4.2.2 Carbon Fiber reinforced polymer

The beam was wrapped with all four sides by CFRP sheets of different thickness that is 0.3 mm [5]. Before providing the CFRP sheet on all sides of beam first made the surface rough and clean by using wire brush and then mixing the epoxy resin properly in any container. After mixing, apply the epoxy primer on beam by using brush for a good bond between the concrete surface and CFRP sheet and the wrap the beam by using CFRP sheet of thickness 0.3mm with single layer or also unidirectional [6,7] and then check it for strength. The retrofitting of beam was kept under room temperature and work also done on room temperature for protecting the moisture. The retrofitted beam cured for 3 days under room temperature.

5. TEST AND RESULTS

Testing of beams

All beams were tested under loading frame machine for the flexural strength. Four beams were casted, all beams tested under point load by using loading machine as shown in figure 5. After testing the crack pattern and crack load were checked and also checked the ultimate load as shown in figure 6.


Figure 5 Experiment test set up and point loading arrangement

Figure 6 Control beam with crack and failure pattern

Table 1 Deflection of control beams at crack load and ultimate load

Crack		Point	Ultimate	Point
Crack load (kN)		**Deflection (mm)**	**Ultimate load (kN)**	**Deflection (mm)**
B1	61	7.4	110	13.2
B2	60	6.3	107	11
B3	61	7.4	110	13.2
B4	55	4.0	105	10.8

Table 2 Deflection of retrofitted beams at crack load and ultimate load

Sr. No.	Crack load (kN)	Deflection (mm)	Ultimate load (kN)	Deflection (mm)
B1 (RC jacketing)	143	20	181	21.6
B2 (CFRP-0.3MM)	121	17.6	152	19.8
B3 (CFRP-0.3MM)	123	17.8	154	19.9
B4 (CFRP-0.4MM)	126	17.9	154	20

At that point the bar was retrofitted and tried once more. The example B1 retrofitted by utilizing RC jacketing and afterward strength was checked by applying point load on specific surface likewise check the pressure and dislodging of all shaft that is control pillar and all retrofitted radiates (table 1 and 2). At the point when burden was applied first break load was checked and redirection of bar and afterward checked a definitive burden. The example B3 and B4 retrofitted by CFRP sheets of thickness 0.3 mm and 0.4 mm with single layer and afterward load was applied and check the strength. In the wake of applying the jacketing on all pillars, contrasting the outcomes and control bar and retrofitted radiates which was retrofit by various strategies and afterward check which was generally reasonable and cost affected techniques and furthermore check the strength likewise the conduct of burden diversion of all bars was looked at. The avoidance chart was plotted. The RC jacketed bar has more strength when contrasted with control and other retrofitted radiates and less in expense too.

It has been discovered that the break heap of bars without retrofit is between 60 kN to 62 kN and extreme burden between 120 kN The control bar has greatest avoidance and less extreme burden conveying limit and shear limit. The break heap of RC jacketed is shaft 120 kN to 140 kN and extreme burden between 180 kN to 200 kN in CFRP jacketing with single layer of sheet the primary break load showed up at 110 kN

Cost comparison: -

The cost of CFRP is large as compared to steel and RC jacketing.
The cost of RC jacketing= cost of (cement+ FA+ CA+ fly ash + Reinforcement)
= (1 bag× RS 360) + (228kg÷1493.56×RS882) + (194kg÷1476×RS2258) + (10kg×RS10) + (1200) = RS2500/-(Labor cost=300/-) = 2800/-
The cost of steel jacketing= cost of steel plates= RS 3000/-
The cost of CFRP jacketing= cost of (CFRP sheet) + (epoxy resin)
(3500+3500+3500) +(400/kg×5) =RS 12500/-

RC jacketing	2500/- or 2800/-
Steel jacketing	3000/-
CFRP jacketing	12500/-

Software analysis

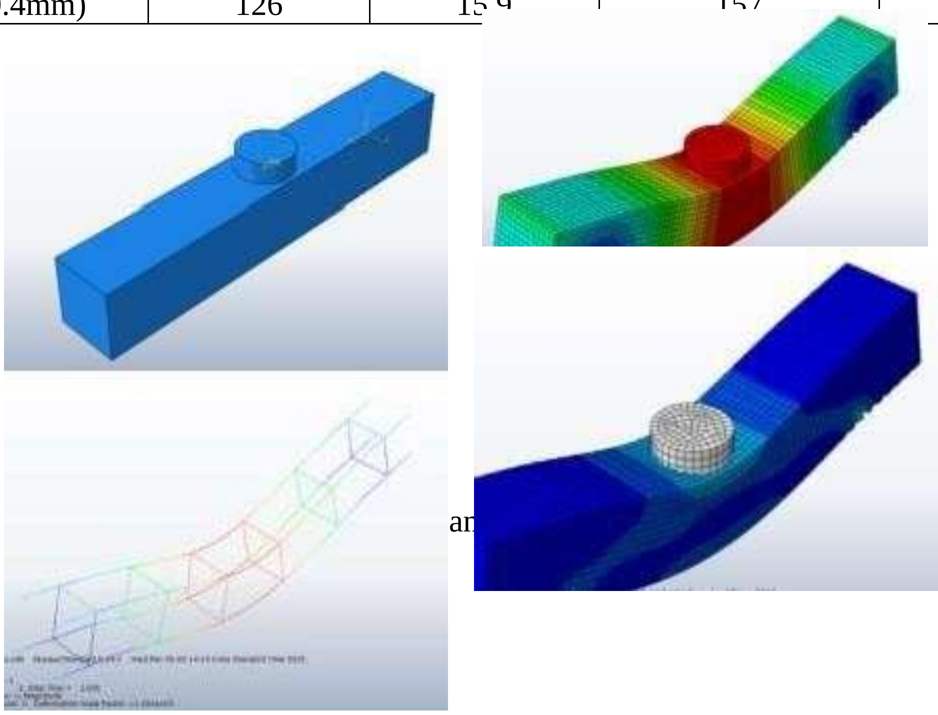
The RC shaft plan in programming ABAQUS with measurement 230×230×1500 mm. First the unique - 2 section were arranged and afterward allot the properties of cement and steel and afterward gather the all parts to make it RCC pillar as appeared in fig 7. The connection part is done to cause the structure to communicate with one another so it shows disfigurement appropriately and characterize the punishment grinding coefficient 0.8 in distracting conduct. The essentially upheld uphold was relegate by utilizing limit condition and applied burden break and extreme burden to check redirection and afterward contrast the outcome and test work. The significant part was fitting which implies that it checks all aspects of hubs.

Table 3 Deflection of control beams at crack load and ultimate load in software

Crack		**Point**	**Ultimate**	**Point**
Crack load (kN)		**Deflection (mm)**	**Ultimate load (kN)**	**Deflection (mm)**
B1	61	5.80	112	11.12
B2	62	5.14	109	9.41
B3	63	5.80	112	11.11
B4	57	3.18	107	9.22

Table 4 Deflection of retrofitted beams at crack load and ultimate load

Sr. No.	**Crack load (kN)**	**Deflection (mm)**	**Ultimate load (kN)**	**Deflection (mm)**
B1(RC jacketing)	143	16.7	181	18.20
B2 (CFRP-0.3MM)	121	14.8	151	16.70
B3 (CFRP-0.3MM)	123	14.8	152	16.68
B4(0.4mm)	126	15.9	157	16.70



Validation

In this it shows that during the test work the greatest redirection and bowing happen at focus of bar and furthermore in scientific work as shown in figure 8.

Figure 8 Deformation in control beam

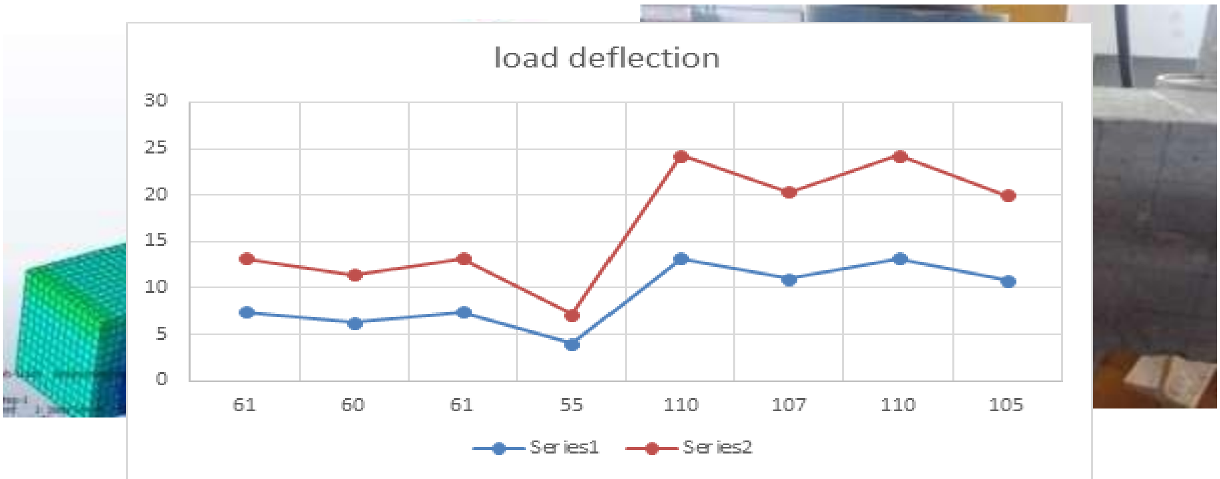


Figure 9 deflection of control beams (Series 1 software results and series 2 experimental

CONCLUSIONS

The flexural conduct of fortified solid shafts reinforces by RC, Steel, CFRP sheets having diverse thickness are examined and explored and following end were made:

1. Due to reinforce by RC, CFRP, extreme strength and bearing limit of pillars expanded.
2. The normal break heap of control pillar and retrofitted by RC was discovered 60 kN to 61 kN and 140 kN extreme heap of control bar however the break heap of retrofitting radiates found between 120 kN and extreme burden 200 kN
3. The extreme strength of RC jacketing increments 63% more than the control shaft and other coat pillar.
4. The extreme strength of CFRP jacketing increment 48.5%more than the control pillar. It was discovered that CFRP is additionally useful for consumption obstruction.
5. All four sides jacketing of bars has more strength and bearing limit. It expands the limit of obstruction as the interest of burden increment.
6. These all strategies help for future to retrofitting the structure either bar, section or additionally characterize the break example, profundity and disappointment load.
7. The expense of RC jacketing is not as much as steel and CFRP, the CFRP has enormous expense when contrasted with steel and RC. Thus, RC jacketing is acceptable in both strength and cost.

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