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REVIEW ON STRENGTHENING OF REINFORCED CONCRETE COLUMNS BY CFRP JACKETING

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ABSTRACT

Seismic protection of buildings is a need-based concept aimed to improve the performance of any structure under future earthquakes. Earthquakes of varying magnitude have occurred in the recent past in India, causing extensive damage to life and property. Some recently developed materials and techniques can play vital role in structural repairs, seismic strengthening and retrofitting of existing buildings, whether damaged or undamaged. But Selection of right materials, techniques and procedures to be employed for the repair of a given structures have been a major challenges. Innovative techniques of the structural repairs have many advantages over the conventional techniques. The FRP is an advanced composite material which is relatively new material in Civil Engineering in order to achieve large deformation before failure occurs and to accomplish and load resisting capacity. Carbon fiber reinforced polymers (CFRPs) are one the stiffest and lightest composite materials, they are much convincing than other conventional materials in many fields and applications. It holds a better choice than reinforcing steel in certain applications. In order to attain large deformation before failure occurs and to enhance an adequate load resistance capacity, RC columns has to be laterally jacketed. Jacketing RC column with FRP improves column performance not only by carrying some fraction of axial load applied to it but also by providing lateral confining pressure to the column externally. Hence in this study the attempt is made to study the behavior of RC column for both Analytical and Experimental investigation under axial loading and also to study seismic behavior (Lateral Stability) of RC column with carbon nylon fiber reinforced composite material (CNFRC) jacketing.

Keywords: RCC Column, Strengthening, CFRP Sheets, Strength, Composite.

I. INTRODUCTION

An earthquake is the shaking of the surface of the Earth, resulting from the sudden release of energy in the Earth's lithosphere that creates seismic waves. Human being faced a large number of natural disasters like earthquake, floods, tornadoes, hurricanes and volcanic eruptions from time to time. The earthquake will happen in many types, and these earthquakes damage the structure. Earthquakes can happen in three main forms, depending on the plate movements that occur beneath the earth's surface. Earthquakes are usually caused when rock underground suddenly breaks along a fault. This sudden release of energy causes the seismic waves that make the ground shake. When two blocks of rock or two plates are rubbing against each other, they stick a little. When the rocks break, the earthquake occurs. It is the modification of existing structures to make them more resistant to seismic activity, ground motion or soil failure due to earth quakes. The retrofit techniques are also applicable for other natural hazards such as tropical cyclones and severe winds from thunder storms. Jacketing is the most popularly used method for strengthening of building column. Jacketing consist of added concrete with longitudinal and transverse reinforcement around the existing column. It improves axial and shear strength of column and major strengthening of foundation may be avoided. Retrofitting is the process of strengthening the structure or the structural elements using different techniques. CFRP Jacketing is a Carbon fiber reinforced polymer jacket used for strengthening, very effective for confinement and shear strengthening. CFRP composites present advantages over traditional confinement technique.

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II. LITERARTURE REVIEW

2.1 Jijin V et al: In this paper the author has been studied the effect of GFRP and CFRP jacketing on RC columns of different cross section shapes such as square, circular and rectangular. The ANSYS 15, software has been used for model and analysis. From the results and discussions made by the author it has been seen that the ultimate load carrying capacity of square columns is (479.52KN) which is greater than the circular and rectangular column by providing the CFRP jacketing.

Table1: Ultimate load carrying capacity of columns

Column c/s Shape	Jacketing Provided	Layers of FRP Jacketing	Ultimate Load Carrying Capacity (kN)
Rectangular	Control	-	140.94
	GFRP	1	164.23
		2	199.27
	CFRP	1	249.49
		2	293.73
Circular	Control	-	257.48
	GFRP	1	287.87
		2	318.57
	CFRP	1	399.98
		2	445.38
Square	Control	-	262.52
	GFRP	1	297.36
		2	333.17
	CFRP	1	369.08
		2	479.52

From this study, the author has been concluded that, GFRP and CFRP jacketing increase the load carrying capacity of columns by providing the additional confinement without increasing the column size.

2.2 M. Leeladhar et al: In this research paper the author has been studied that about the retrofitting of reinforced concrete beam using CFRP jacketing. In this paper an RCC structure has been designed and analyzed with linear static analysis in E-Tabs. The number of floors has been increased over a G+5 structure and due to increase of floors the design load was increased. Some of the existing columns were failed and these are retrofitted using 2mm thick CFRP jacketing technique in ANSYS 15, to increase the strength and to meet the current design requirements. After studying the author has been made some results and discussions,

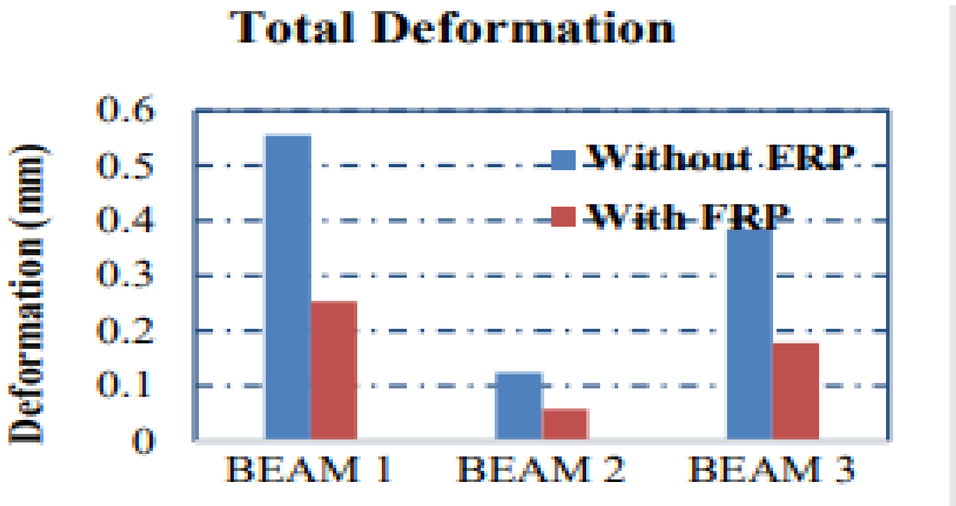

Figure 1: Comparison of deformation before and after jacketing

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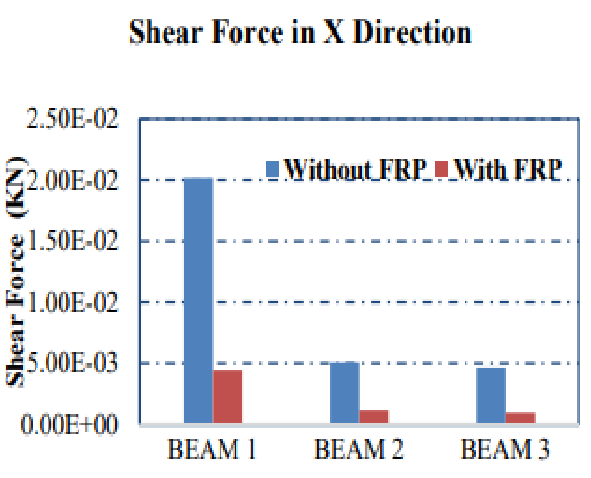


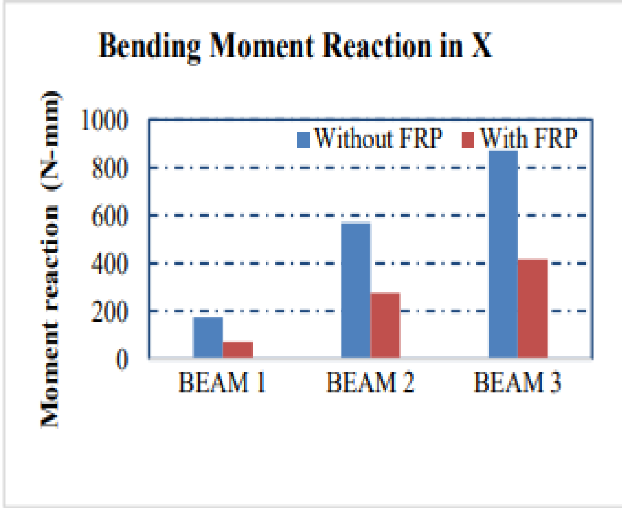


Figure 2: Comparison of bending moment and shear force before and after jacketing

After all the study the author has been concluded that, The total deformation is reduced by 45.66%, 46.82% and 46.28% for beam 1, 2 and 3 respectively when CFRP wrapping is introduced. The Shear force is reduced by 22%, 23.48% and 20.61% for beam 1, 2 and 3 when CFRP wrapping is done. Bending moment is reduced by 41.41%, 48.4% and 47.73% for beam 1, 2 and 3 when CFRP wrapping has done.

2.3 Mansoor ahmad bhat et al: In this paper authors been carried out a research work on retrofitting of RC beams by using CFRP Sheets. In this study an experimental work is carried out for RC beams retrofitted using unidirectional and bidirectional CFRP sheets. The main aim of this study is to investigate the behaviour of RC beams after retrofitting with CFRP sheets. After the both control and retrofitted beams were tested for Flexural strength, following resultant and discussion were made by the authors in terms of deflection and load carrying capacity.

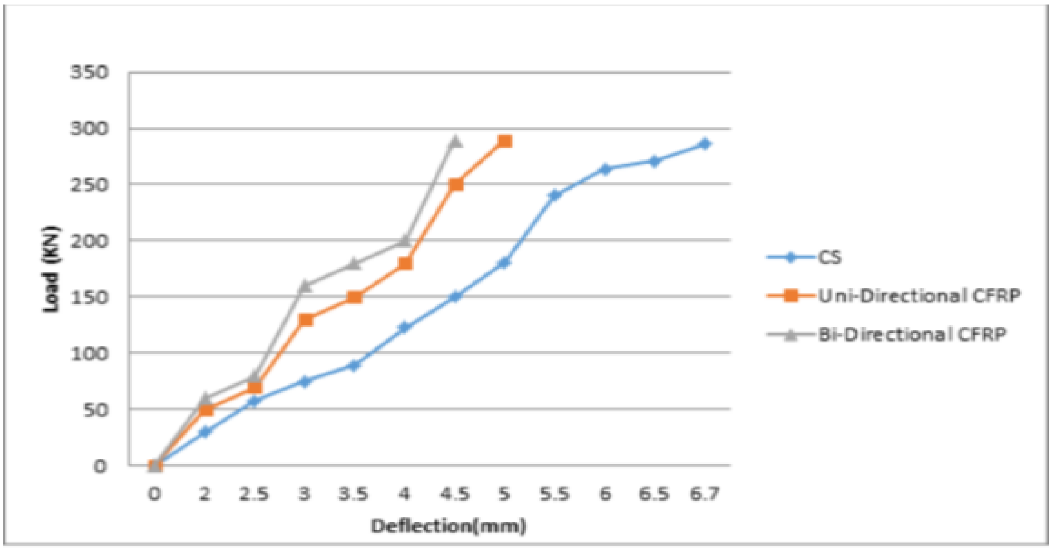


Figure 3: Load vs. deflection graph

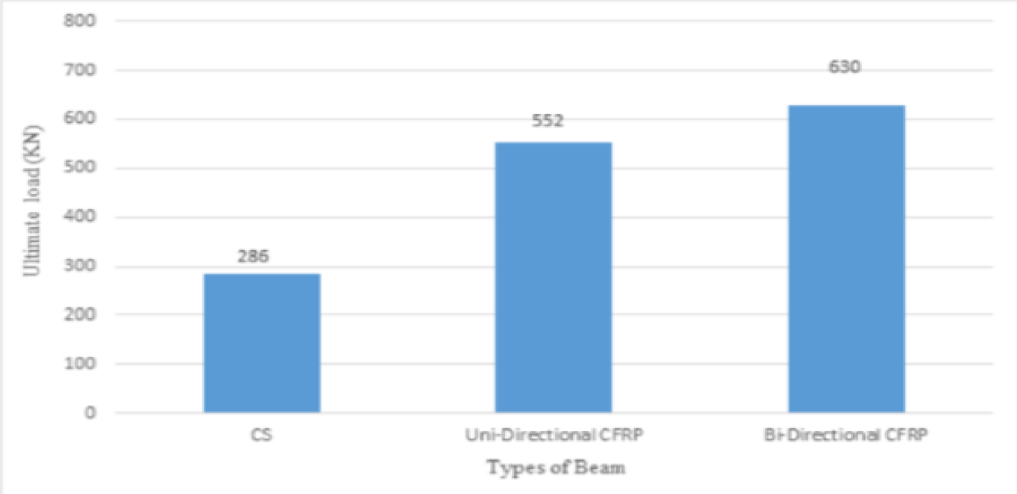


Figure 4: Comparison of ultimate load capacity

It has been found that all the beams retrofitted with CFRP sheets have better load deflection characteristics than the control beams. It has been also seen that the ultimate load of control beam was 286KN where as the ultimate load of retrofitted beams had greater than 550KN that is the load carrying capacity of the beams retrofitted with unidirectional and bidirectional CFRP sheets increased by 93% and 120% respectively than control RCC beam. From this study the authors have been concluded that due to strengthening of beams with CFRP sheets externally the ultimate load bearing capacity and the Flexural strength of the beams increased and it has been also concluded that due to full rapping technique of CFRP around all the four sides of the RCC beam deflections can be reduced.

2.4 Saleel Visal et al: In this paper the authors has been presented a research work on review paper on properties of carbon fiber reinforced polymers. Carbon fiber reinforced polymer [CFRP'S] is one of the stiffest and lightest composite materials. They are much convincing than other conventional materials in many fields and applications. Use of composite is limited due to their higher rise and lower formability and one or more properties of CFRP's are nano particles. Use of nanoparticles increases mechanical properties of these composites. And composites like Fiber reinforced are considered to replace metallic components in many industries for past several years. Because of comparing to conventional metals fiber reinforced composites have low density, high specific strength and stiffness, higher corrosion resistance. In this study a different loading conditions are carried out to check the performance of fiber reinforced composites. Such as axial, torsion and impact loading is very crucial for the design of structural components. Among these all properties carbon fibre reinforced polymers are emerging because of remarkable properties of carbon fibers and polymer matrix combination. It has also seen that CNTs [carbon Nanotubes] are the strongest materials and are most widely used because of their strong interfacial interactions and excellent stress transfer properties.

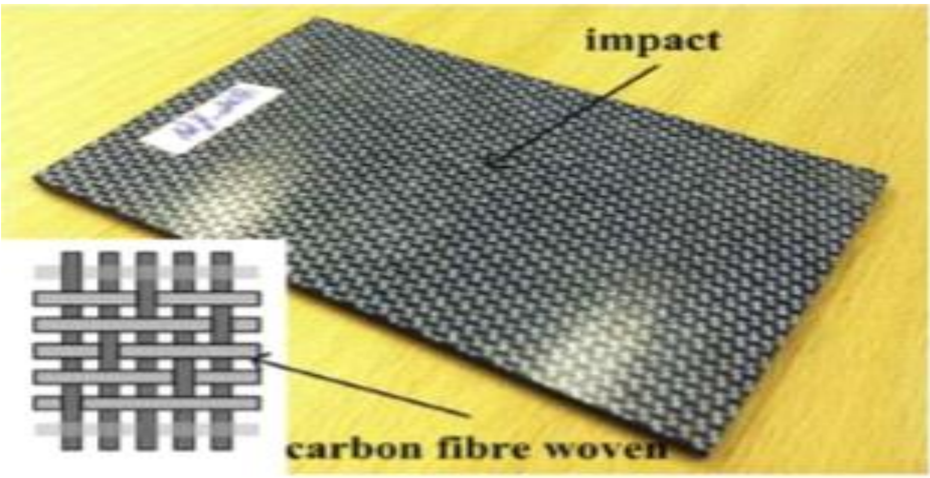


Figure 5: General impact

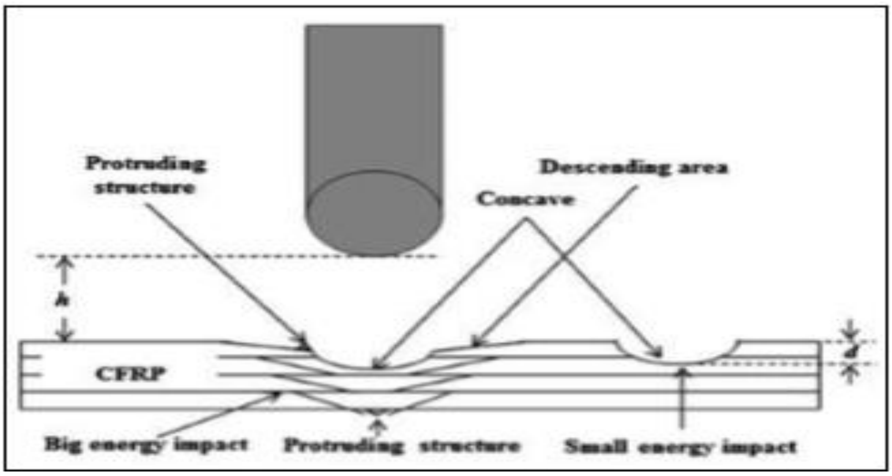
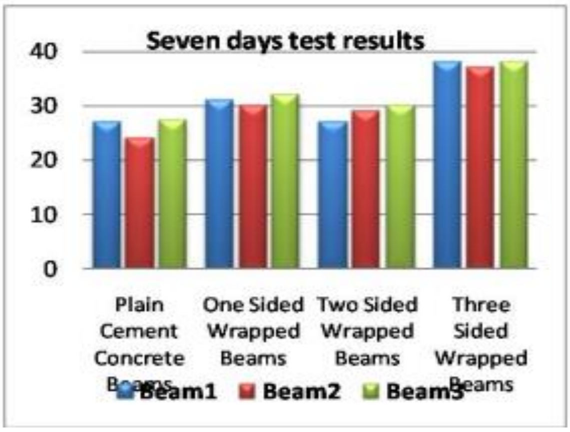


Figure 6: Picture of CFRP impacted laminate characteristics for CFRP structures

When impact energy increases more and more partial carbon structure will break down decreasing its conductivity, therefore increasing resistivity. From this study authors have been concluded that addition of CNT or nanoclay which in this case is montmorillonite nano clay properties of CFRP are showing increasing and enhancement.

2.5 Ms. Raksha.j.khane et al: This study shows the several situations in which a civil structure would require strengthening due to more strength stiffness, durability and ductility of beams, columns and plates elements maybe strengthened in flexure with the use of CFRP bounded to their tension zone using epoxy as a common binder due to several advantages of carbon fiber wrapping over conventional techniques used for structural repair and strengthening the use of CFRP has becoming popular In this study the author has taken three beams B1, B2, B3 cured for 7days and 28 days where tested on flexural testing machine. The beam wrapped with CFRP at one side, two sides parallel, and three sided continuous and the results are compared with normal plane cement concrete beam and the beam wrapped with the one side CFRP shows the increase in strength up to 20% and the beam wrapped with the two sided parallel shows the increase of 10.69% and the beam which is wrapped with the three side shows the results of 42.50%, at the last the author concluded that the beam which wrapped with the three sided is giving the high strength.



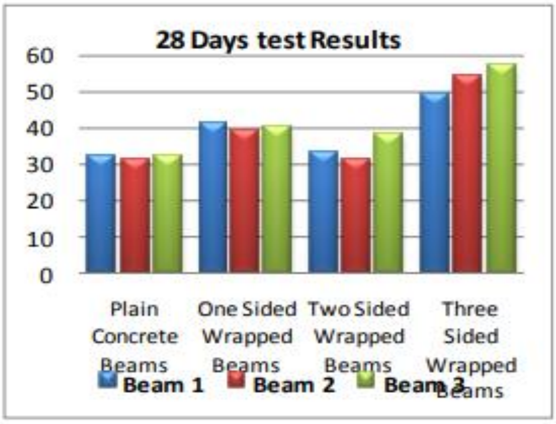


Figure 7: 7 days and 28 days flexural strength test results

Table 2: Percentage increase in strength of different wrapping

Sr.No	Beam description	Increase in Strength comparing with Plain Cement Concrete beam. (%)
1	strength of the beam wrapped tension side	20
2	strength of the beam wrapped at two parallel side	10.69
3	wrapped at three side	42.50

2.6 V. Mohanlakshmi et al: In this research paper the author has reviewed the possibilities and methods in practice for wrapping the beam-column joints. This paper also summarizes the scope and uses of FRP materials such as CFRP and GFRP. As per the literature studied by the authors, some of the literature presents that the exterior beam-column joints is retrofitted to enhance their strength and stiffness. Two specimen one is un-strengthened and another is strengthened specimen with CFRP were modeled and analyzed. These specimens are then loaded with step by step load increment procedure to stimulate the cyclic loading in testing. The stress and deformation results were evaluated and compared their results with strengthened and un-strengthened specimen. The numerical results shows that the beam-column joints strengthened with CFRP can increase their structural stiffness, strength and energy dissipation capacity. Another literature studied by the author carried out the study of failure modes, flexural strengthening effect on ultimate load and load deflection bonded externally with JFRP, CFRP and GFRP, wrapped in configuration in single layer, along the entire length of the beam in full wrapping and strip wrapping technique. The results show that the JFRP, CFRP and GFRP strengthening improved the ultimate flexural strength of the RC beams. From the studies, the author have been concluded that the CFRP and GFRP sheets are being very effective in improving the shear resistance and deformation capacity of the exterior and interior beam-column joints and delaying their stiffness degradation during seismic activities. CFRP and GFRP wrapping on beam column joints increase the ultimate flexural strength of the structure and reduces the shear failure.

2.7 Shri. Pravin B. Waghmare: In this paper authors has been carried out a research work on materials and jacketing technique for retrofitting of structures .In this study a technique work is carried out for retrofitting of structures using different methods of jacketing. Such as steel jacketing, reinforced concrete jacketing, fiber reinforced polymer composite jacket, jacket with high tension materials like carbon fiber, glass fiber etc. The main aim of this study is to increase the seismic capacity of the moment resisting framed structures and also the purpose of jacketing is to increase the shear strength by transverse fiber reinforcement. It is also observed that jacketing of column is not successful for improving the ductility and the main advantage of column jacketing is that, it improves lateral load resisting capacity of the building.

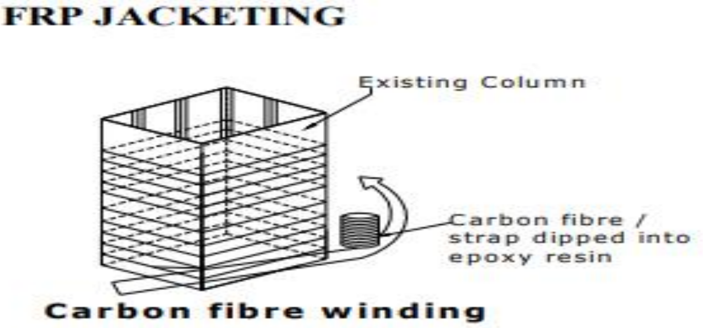


Figure 8: Carbon fiber winding

Many researchers have been investigated the chances and conventional of fiber reinforced polymer composite jackets for seismic strengthening of column winding them with more strength carbon fiber around column surface. It has been found that carbon fiber is flexible and made to contact the surface strongly for higher degree of confinement because carbon fiber is of high strength and high modulus of elasticity. As well as carbon fiber has light weight and rusting does not take place. It has been also seen that the jacketing of beams is recommended for several purposes as it gives continuation to the columns and increase the strength and stiffness of the structure as well as in the retrofitted structure, there is a strong chances of change of mode of failure and redistribution of forces as a results of jacketing of column. Comparing to steel jacketing local strengthening of columns has been frequently accomplished by jacketing with steel plates. Steel jacketing increase the bearing capacity and it is more in ductility and rigidity of components. This construction is simple and easy to conduct. Jacketing of beams may be carried out under different ways, the most common are one sided Jackets or three-four sided jackets. From this study the change in behavior of jacketed elements, whose shear span/depth ratio, strengthening are possibly reduced, due to their jacketing.

2.8 JIJIN V et al: In this paper the authors carried out a research work on comparative study of GFRP jacketed RC column and CFRP jacketed RC columns of different shapes. In this research work a comparative study on

GFRP jacketed and CFRP jacketed RC columns of different shapes having same cross sectional area were analyzed. Buckling analysis has been done using ANSYS 15. From the analysis the authors stated that CFRP jacketed RC columns shows a better load carrying capacity than GFRP jacketed RC columns subjected to buckling load. From the results and discussions made by authors, the GFRP and CFRP jacketed RC columns subjected to buckling load increases the load carrying capacity. The load carrying capacity is more for square than circular and rectangular RC column. Hence the load carrying capacity increases when two layers CFRP and GFRP jacketing is provided. From this study the authors concluded that GFRP and CFRP jacketing enhances the buckling load carrying capacity providing additional confinement without increasing the column size and also CFRP jacketing is found to be more effective than GFRP in case of buckling loading.

2.9 P.VIJAYAKUMAR et al: In this research paper the authors carried out a research work on retrofitting of flexural deficient beams using CFRP. In this study the performance of conventional and retrofitted beam using CFRP bounded with epoxy resin and hardeners which are weak in flexure theoretically and experimentally has been studied. The total six beams were casted and in which three conventional and three retrofitted by reducing main reinforcement from 100% to 70% to 50% so as to assess the flexural strength and damage level of the beams under weak in flexure condition. The retrofitted specimen at bottom side of CFRP has been attached, where additional resistance may get produced and leads to load carrying capacity of beams. In order to calculate the neutral axis depth of retrofitted specimen, equate it with equilibrium force, Cu=Ts+Tc*frp-eqn(1) and 0.36*1.5*fck*b*xu=(1.25*fy*Ast)+(Ac*frp*fc*frp). From the results and discussion made by the author, for BWFC100 the applied load was 56KN and also for BWFR100 it was 75KN by theoretical calculation. The experimental results of ultimate load carrying capacity for BWFC100 was 135.4KN with maximum deflection of 25.97mm where as for BWFR100 it was 193KN with maximum deflection of 19.51mm.

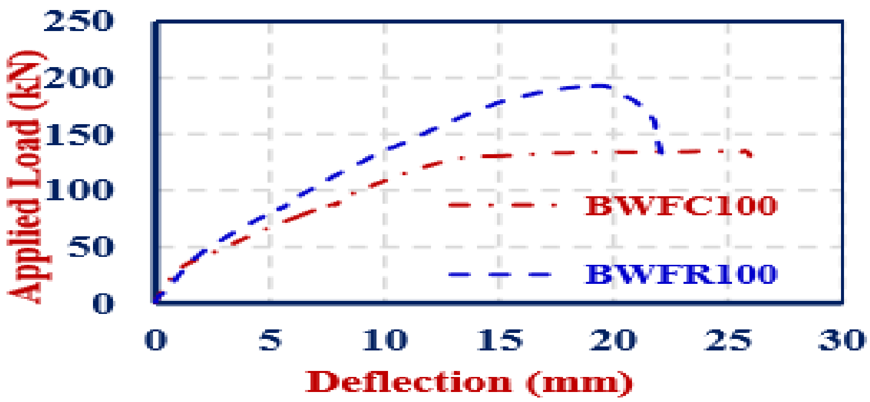


Figure 9: Comparison of Flexural Strength of BWFC100 and BWFR100.

From this study they have concluded that the ultimate capacity of BWFR100 was increased by 42.54% compared with BWFC100 and also concluded that retrofitting using CFRP sheets has been recommended in order to enhance the flexural strength of beams.

2.10 Fathollah sajedi et al: In this paper the authors have compared the results of axial compression testing on reinforced concrete columns made with high-strength concrete (HSC) and confined by glass fiber-reinforced plastic (GFRP) casing and carbon-fiber reinforced polymer (CFRP). In this study, six cylindrical HSC-reinforced concrete columns (150mm diameter and 600mm height) were prepared and divided into two groups. In each group, one column without CFRP, a column was wrapped with one CFRP layer, and another column with two CFRP layer. The concrete compressive strength was taken as 63.1MPa. All the columns were tested under compression capacity load. The result shows that the utilization of CFRP and GFRP casing improved compression capacity and ductility of reinforced concrete columns. After studying the author has made some results and discussions which shows that the addition of one and two CFRP layer wrapping increased compression capacity to an average of 10.2% and 24.8% respectively; while the use GFRP casing increased compression capacity of the HSC by 3.38 times.

2.11 K.GANESH et al: This paper presents behavior of Reinforced concrete columns wrapped by CFRP under eccentric and concentric loading. In this research work performance of a column of compound material (concrete and steel, RCC, CFRP) so as to improve the flexural strength of the column was studied which was

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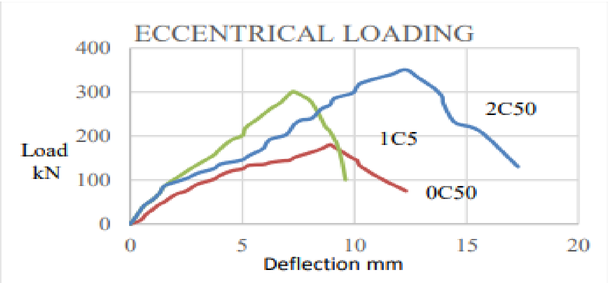
subjected to eccentric and concentric loading. In a conventional RCC column, the compressive load is sustained by both concrete and steel; the flexural and tensile loads are sustained by steel alone. In any way the eccentricity loads are two types one is purely uni axial load and the other one is biaxial load. Among these two this paper describes behavior of purely uni axial load columns by wrapping with CFRP. The experiment was carried out in three groups of a total of six columns. Each group consists of two columns, Group consists of two RCC columns without wrapping CFRP fabric, Group B consists of two columns with confinement by CFRP fabric of one layer and Group C comprises two columns with confinement by CFRP fabric of two layers.

Table 3: values of concrete columns tested

Type of section	Ultimate load in KN	Axial displacement in mm	Eccentric displacement in mm
GROUP A	257	5	
	180.30	-	8.9
GROUP B	415.60	6.3	
	300.60	-	7.3
GROUP C	560	8.7	
	350.60	-	12.3

From the above results and discussion of the experiment, the Group A unwrapped columns the mild cracks were observed with the entire column and after some loading point concrete material spelled concentric loading point at top and bottom and while in eccentric test column experienced crushed and later displacement. In Group B columns failure was like Group A only but crossed the limit of Group A column strength and maintained some significant performance then after it collapsed and CFRP peeling sounds appeared and after some point CFRP showed the tensile nature and fabric teared with some concrete material in concentric test. At the time the eccentric point column displaced laterally and suddenly busted CFRP fabric with peeling sound. Following Group C failures were observed like Group B only but in Group C showed the CFRP bearing a larger load than expected, the two layer fabric is said to be significant in load carrying capacity.



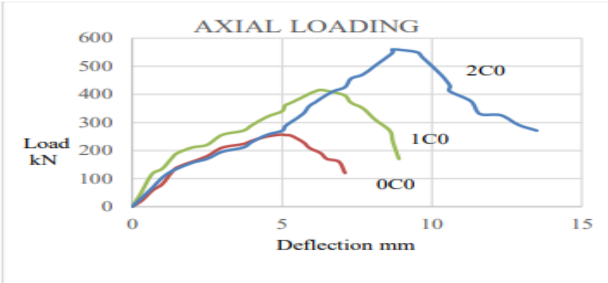


Figure 10: deflection values under different loading conditions.

From this study the author has concluded that CFRP wrapped bears huge load carrying capacity in reinforced concrete components, as per test results CFRP wrapped columns performed better than the conventional columns even in eccentric loading.

2.12 K.OLIVOVA et all: In this paper authors have carried out a research study on strengthening concrete columns with CFRP. This paper presents the experimental study on the structural behavior of reinforced concrete columns strengthened with carbon fiber sheets and strips in pre-cut grooves. The main aims of these experiments were to investigate the effects of additional strengthening of reinforced columns. The bond behavior analysis has been required for understanding the stress transfer process between concrete and CFRP, this study also included a pull-out test for assessing the bond characteristics of a CFRP strip. The pull-out test of the laminated strip inserted in a groove in a concrete fragment specimen was done in order to find the anchor length. A concrete cube was placed in a tension testing machine. Two alternative failure modes were observed in the experiments, namely, either the pull-out at the interface between CFRP lamina strip and epoxy paste or the rapture of the CFRP strip. The results from this test were taken into account during the application of laminated strips on the strengthened concrete columns and indicated sufficient anchorage length of the CFRP laminate strip in the footing was 100mm. The first sample series consisted of non-strengthened reinforced concrete (RC) columns, the second sample series consisted of concrete columns strengthened with CFRP laminate strips before testing: the third series was composed of columns strengthened with CFRP laminate strips and sheets. Each specimen was composed of a column connected to foundation blocks. The linear variable displacement transducers (LVDTS) were used to record the horizontal and vertical displacement of the column and footing respectively. From this study authors had concluded that the strengthening technique proposed by the near surface mounted (NSM) technique is promising for increasing the load-carrying capacity of concrete columns failing in bending.

III. CONCLUSION

From the review of the literature collection, it is observed that the strengthening / retrofitting plays a vital role to improve the failure of structures. From all these papers some conclusions are drawn:

1. The ultimate load carrying capacity of square column is better than circular and rectangular column by providing the CFRP jacketing.
2. By providing the CFRP wrapping to the beam the total deformation, shear force, bending moment, are significantly reduced.
3. The beam-column joints strengthened with CFRP can increase the structural stiffness, strength and energy dissipation capacity.
4. Due to strengthening of beams with CFRP sheets around all four sides externally, the ultimate load bearing capacity, flexural strength of beam increases and deflection reduces.
5. The change in behavior in jacketed elements whose shear span/ depth ratios are significantly reduced.
6. The ultimate capacity and maximum deflection of retrofitted beams using CFRP bond with epoxy resin is better than conventional beams.
7. The specimen wrapped with CFRP and GFRP significantly increases the ductility and energy absorption capacity.
8. The strengthening technique proposed by the near surface mounted (NSM) technique is promising for increasing the load carrying capacity of concrete columns failing in bending.

IV. COMMENTS

1. Load carrying capacity of the columns can be increased by using CFRP sheets.
2. CFRP column jacketing technique will be more effective than the GFRP jacketing technique.
3. CFRP jacketing enhances the axial load carrying capacity by providing additional confinement without increasing the column size.
4. Lateral stability of the columns can be increased by using some composite materials along with CFRP like nylon, CNT's (Carbon Nanotubes) and Nano Clay.

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