Performance Review of Square Slender RC Columns Swaddled With Carbon-Fiber Reinforced Polymer Sheets Loaded Axially

[1]ANAND, [2]Dr. RAJEEV CHANDAK

[1]Master's Student, [2]Professor and Head
Civil Engineering Department
Jabalpur Engineering College, Jabalpur, India

Abstract— **Retrofitting of structural members has been a common practice for long time now. In this regard, retrofitting and strengthening of columns has been done since a long time. Keeping aside the conventional methods such as steel jacketing, this paper focuses on the use of Carbon Fiber Reinforced Polymer Sheets for increasing the strength and life of long columns. Long columns have a tendency to fail due to bending. Our work emphasizes on the significance of CFRP sheets if it can delay or avoid bending failure. In this work it was found that the strength of long columns specimens was enhanced up by 124.5%, if doubly wrapped by CFRP using epoxy adhesive and resin. The columns were wrapped in different percentage of their surface area such as 0%, 65%, 100% and 200% (or doubly wrapped). CFRP used negligible space in comparison to other conventional methods which adds up to the pro of carbon fibers sheets. Also the failure pattern suggests that the failure occurred at the supports indicating avoidance of failure due to bending.**

Index Terms—Carbon-Fiber Reinforced Polymer, Retrofitting, Strengthening, Long columns, Slender Columns

I. INTRODUCTION

With steady growth in research based on strengthening of existing and new columns, Carbon Fiber Reinforced Polymer (CFRP) has found its own significance. Several previous works on short and slender columns show that CFRP delivers serious results in delaying failure with significant increase in load. This study aims to strengthen the facts and finds of previous researches on short columns whereas to verify the quality of impact CFRP has on the strength of slender columns.

A column is considered deficient when it has a low concrete compressive strength and insufficient longitudinal and lateral reinforcement. This deficiency could be attributed to several factors: exposure to severe environmental conditions that cause concrete deterioration, excessive external applied loads due to the change in the structure occupancy, and changes in design codes requirements. Strengthening a column means enhancing its axial strength and ductility (i.e. withstanding more axial load and deformation). It is also well known that failure mechanism of columns depends upon its slenderness ratio. The greater the slenderness the more bending property is infused into the column due to which while working on strengthening it becomes important to consider the ratio of effective length to least radius of gyration effectively known as slenderness ratio. The main objective of the study is to find if Carbon fiber Reinforced Polymer (CFRP) can be a sustainable alternative to other retrofitting methods.

Conventional methods of jacketing including the post tensioning techniques provide satisfactory results but contain some serious drawbacks. The drawbacks are as follows:

- Steel add to the dead weight of the columns which may to enhancement of seismic loads.
- These construction methods are huge and time taking in nature and may result in disruption in traffic flow.
- Increase in mass may increase the stiffness of the structure which in turn can reduce the time period and consequently leading to destruction.
- The use of these conventional techniques also affects the aesthetics.

As the conventional methods contain the above serious drawbacks researches around the world have focused on substitute. In this regard Carbon Fiber polymer has emerged as a serious contender.

II. LITERATURE REVIEW

Concrete column cross sections, reinforced laterally with steel, have a core portion enclosed or confined with steel and a part that includes the cover of unconfined concrete. At low levels of stress in concrete, both parts behave similarly as unconfined concrete, and steel has no effect. However, as the stress level in concrete is increased and approaches the post-peak loading history, the transverse steel effect increases considerably. Once the compressive strength of the unconfined concrete (f_c¢) is reached, the concrete cover becomes ineffective. As the stress increases under applied load, the concrete expands outwardly and the internal cracks increase leading to high stress in transverse steel which applies a confining response to the concrete (Kent and Park 1971) and places the core in a state of tri-axial stress.

Pranay Ranjan and Poonam Dhiman 2016 studied a particular problem statement of a building in Patna, Bihar. The paper focuses on the design of the RC jacketing, steel jacketing and FRP jacketing of the same column and their cost variation. According the study Fiber reinforced polymer jacketing is least economical whereas steel jacketing costs least. The paper concludes that the use of FRP Jacketing offers several advantages over the RC and SFRC Jacketing but it is slightly expensive.

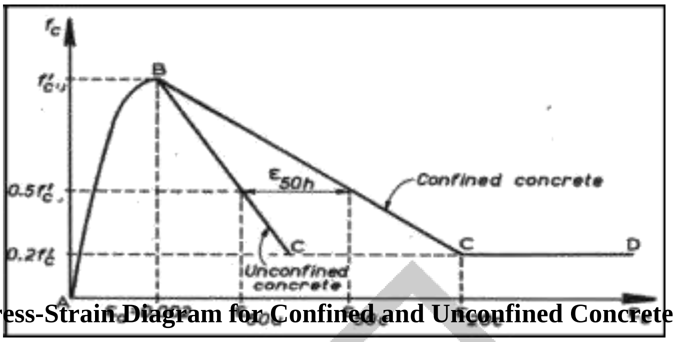


Fig 1: Stress-Strain Diagram for Confined and Unconfined Concrete (Kent and Park, 1971)

The use of Carbon fiber reinforced epoxy composites modified with carbon nano tubes in strengthening Mohhamad R. Irshidat et al 2015 the reinforced columns by wrapping them with fiber sheets blended with neat epoxy or CNTs modified epoxy. Under concentric axial loading the test results concluded that the wrapped columns gained a strength of 24%, maximum displacement of 109% and toughness of 232% with respect to unwrapped RC column.

Muhammad N.S. Hadi 2006 presented the results procured by testing wrapped columns subjected to eccentric loads. This paper provided a description of the loading mechanism and results of testing nine prismatic circular columns tested under eccentric load. The columns were wrapped with CFRP or GFRP. Nine short cylindrical high strength concrete columns were designed for testing. Three columns were reinforced with steel bars and the remaining six columns were made of plain concrete. Three of the six plain columns were wrapped with unidirectional carbon while the remaining three columns were wrapped with weave E-glass. In his conclusion, external confinement with FRP composite appeared to significantly augment the strength of concrete column. However, when the eccentric load was introduced into the experiment, the strength loss was vastly evident. In addition, the maximum load capacity of a confined column under eccentric load was directly related to the magnitude of eccentricity. That is, a larger eccentricity results in a smaller maximum load. However, the lateral deflection—another important design criterion—had no direct relation with the eccentricities. Furthermore, externally confined concrete column could undergo large deformation without rupture (the extent of deformation could be decided by the strength of FRP composite). Finally, when tested both concentrically and eccentrically, the CFRP wrapped columns resulted in higher loads and ductility as opposed to GFRP-wrapped and steel-reinforced columns.
P.Paultre et al 2015 in their research underlined that deficient columns used in bridges can be provided extra enhanced strength or can be upgraded by the use of surface fiber reinforced polymer sheets. As the work focuses on the columns used in bridges, the columns are loaded with cyclic flexure. Under cyclic flexure loading the behavior of the confined columns revealed that FRPs can be effective even in cyclic flexural loading. The results also showed that the addition of CFRP increases the ductility and energy dissipation. For the columns with transverse steel reinforcement spacing and lower axial load the results are more pronounced.

III. METHODOLOGY

Carbon Fiber Reinforced Polymer

The properties of Uni directional CFRP sheet used were as tabulated below:

Characteristics	Value	Tolerance	Test Method
Weight(g/m^2)	230	± 3%	ASTM D3801
Width(mm)	500	-0/+10mm	ASTM D3774
Dry Fabric Thickness(mm)	0.25	± 0.03mm	ASTM D1777

CFRP Used

Epoxy Adhesive

Epoxy resins are used for high strength bondage in civil engineering and thus epoxy adhesive the following properties were used:

Viscosity	Density	Gel Time	Full Cure time
9000-12000 MPas	1.15-1.20 g/cc	2 hours	24 Hours

i. **Specimen Layout**

A total of 8 specimens were prepared in accordance with the need of the research. As the research focuses on behavior of slender columns the experimental set up was prepared to fulfill the needs of the research.

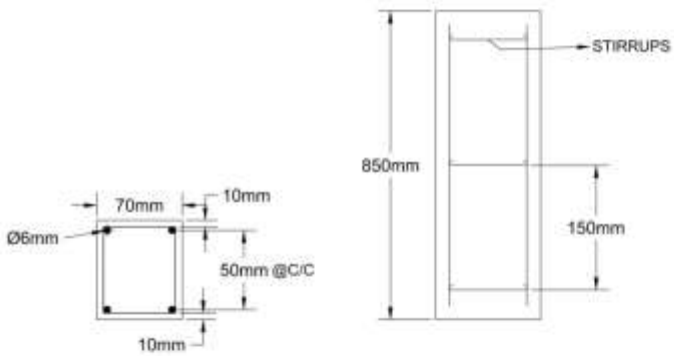
Details of column specimen/Model

The columns were reinforced with 4nos of 6mm diameters plain bars with stirrups at a distance of 150mm each. M20 concrete was used. The columns were cured for 28 days.

Specifications of the Model Specimens of Long Column:

No. of specimen prepared	Height of the specimens(mm)	Width of the specimen(mm)	Cross sectional area of the specimens(mm^2)	Slenderness ratio of the specimen
8	850	70	4900	12.14

The outline of the colimn specimen has been shown below which includes its dimemsions:



Dimensions of Long Column Specimen

These specimens were swaddled with Carbon Fiber-Reinforced Polymer Sheets in three different manners. To study economic parameters and gauge the strength enhancement of the columns with different percentage of CFRP wrapping, the columns were wrapped 65% (single layer), 100% (single layer) and 200% (double layer of complete wrap) of their surface area.

ii. Test set-up

The specimens prepared were tested with axial loading under the Universal Testing machine (long column) All the eigh specimens were axially. Firstly, the specimens with zero percentage of wrapping were tested and the ultimate loads were noted. Secondly, the specimens with 65% of wrapping were tested and the same procedures were applied to the 100% and 200% wrapped specimens. The ultimate loads of all the specimens were tabulated. The ultimate loads were converted to ultimate stress and the comparison was plotted. For each percentage of wrap two specimens were prepared to negate any human error. A total of sixteen specimens were prepared. All the ends of both short and long columns were not restrained against rotation.
The details are provided below:


T

Test setup for long column specimens

IV. RESULTS AND DISCUSSIONS

The above specimen layout and test set up were used to produce the results of the research work. Every column specimen underwent the axial loading and their ultimate loads were noted down and certain interpretations were drawn. As stated in the introduction part we, in this research work were interested in the ultimate load/stress that the specimen can resist and the increase in the cost of the CFRP wrapped specimens with respect to unwrapped specimen.

The ultimate load (P_{ult}) at which the columns fail has been tabulated. In addition to this Ultimate stress (σ_{ult}) has been used to evaluate the performance of the columns.

Result for Column Specimen:

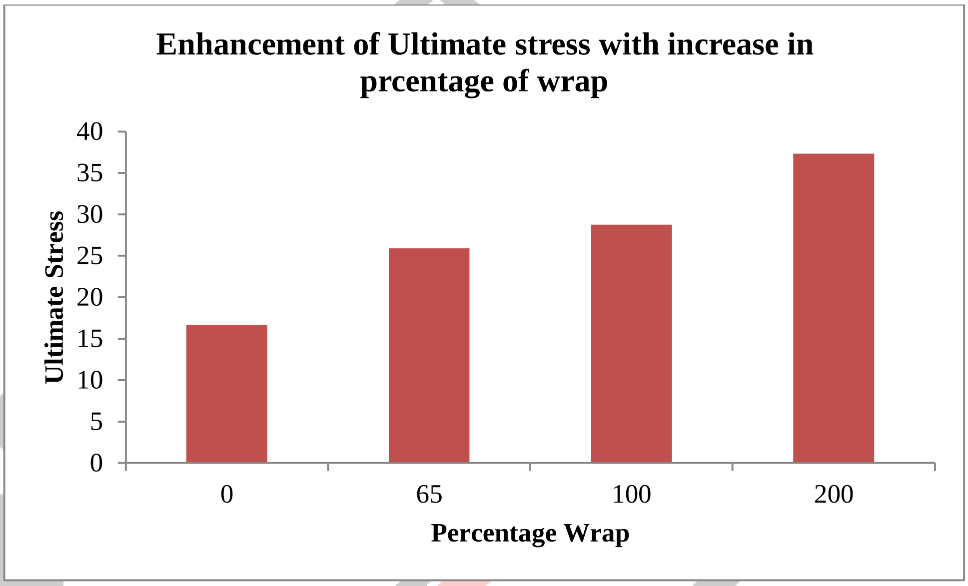
The long column (slenderness ratio>12) gave the following results:

S.No	Specimen Name	Percentage wrapping	P_{ult}(kN)	σ_{ult} (P_{ult}/A) (MPa)	σ_{ult} Considered for calculation(MPa)
1	LC_1	0%	83	16.93	16.63
	LC_2		81.5	16.63	
2	LC_3	65%	138	28.1	25.91
	LC_4		127	25.91	

3	LC_5	100%	141	28.77	28.77
	LC_6		151	30.81	
4	LC_7	200%	198	40.40	37.34
	LC_8		183	37.34	

The above results can be interpreted in the following statements:

- On an average the 65% wrapped column (LC_3 and LC_4) showed an increase of 55.83% in the ultimate load/stress resistance with respect to 0% CFRP wrapped (LC_1 and LC_2) long column specimen.
- The long column specimen LC_5 and LC_6 which were fully wrapped (single layer) with CFRP sheets i.e. 100% wrapped showed the least growth of 73% in the ultimate load/stress with respect to 0% wrapped column specimen.
- The specimen doubly wrapped on the surface with CFRP sheets i.e. 200% wrapped columns produced the least enhancement of 124.5% in the ultimate load/Stress resistance with respect to 0% wrapped column specimen.



Failure pattern in the case of long columns has been shown in the figure below which suggest that the failure due bending was avoided.

Failure of long column specimens at the ends

V. CONCLUSIONS

The results obtained for the slender column specimens with the discussed test setup were analyzed keeping in view the pre decided objectives. The analysis concluded as enumerated below:

1. CFRP is a sustainable substitute to steel jacketing or other conventional methods as it consumes far lesser time and space than those conventional methods.
2. In case of long columns, the increase in the ultimate load and stress value establishes the fact that Carbon fiber reinforced polymer sheets is capable of enhancing the strength and also delaying the failure, though the failure pattern remains the same.
3. The cost for preparing a long column specimen wrapped with 100% surface area wrapped with CFRP was 50%more than that of 0% wrapped specimen which in return resulted in a strength enhancement of around 73%. This cost went up to 75% for Long columns which were doubly wrapped but the strength enhancement is 124.5% which is significantly encouraging.
4. All the long column specimens were found to fail at supports indicating that failure due to bending was avoided as the resistance towards bending improved.

REFERENCES

[1] P.Paultre, M. Boucher-Trudeau, R.Eid and N.Roy "Behavior of Circular Reinforced-Concrete Columns Confined with Carbon Fiber–Reinforced Polymers under Cyclic Flexure and Constant Axial Load" ASCE, Journal of Composites for Construction, 2015

[2] Pranay Ranjan, Poonam Dhiman "Retrofitting of Columns of an Existing Building by RC, FRP and SFRC Jacketing Techniques", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), AETM, 2016

[3] IS 456:2000, Plain and Reinforced Concrete, Bureau of Indian Standards, New Delhi, 2000.

[4] Materials and Jacketing Technique For Retrofitting Of Structures, Shri. Pravin B. Waghmare, International Journal of Advanced Engineering Research and Studies,2011.

[5] Katrnia Gajdosova and Juraj Bilcik, Full-Scale Testing of CFRP-Strengthened Slender Reinforced Concrete Columns

[6] Mohhamad R. Irshidat, Mohammed H. Al-Saleh, Mahmoud Al-Shoubaki, "Strengthening RC Columns Using Carbon Fiber Reinforced Epoxy Composites Modified with Carbon Nanotubes", World Academy of Science, Engineering and Technology International Journal of Materials and Metallurgical Engineering, Vol-9,2015

[7] Analysis & Design of R.C.C. Jacketing for Buildings-Vedprakash C. Marlapalle, P. J. Salunke, N. G. Gore