An Experimental Study on Behavior of RCC Columns Retrofitted using CFRP

P. Murali Krishna, M. Anil Kumar

Abstract:Reinforced concrete structures may be deficient due to various reasons such as improper design of structural elements, deficiency of reinforcement provided,assuming load carrying capacity which is insufficient, etc., from many investigations it is proved that wrapping carbon fiber reinforced polymer (CFRP) can be effective solution for confining and strengthening of deficient RC columns. In this experimental study the behavior of CFRP Wrapped structurally damaged small scale square RC columns having cross-sectional area 150mm x 150mm and height of 1500mm with a nominal cover of 20mm have been tested under axial compression under loading frame. These damaged columns are retrofitted with CFRP by providing corner radii of 5mm, 20 mm(nominal cover), are wrapped with CFRP. These retrofitted specimens are tested under Uni-axial compression on loading frame. The results showed that smoothed edges of square cross-section of Reinforced Concrete columns played a significant role in delaying the rupture of the CFRP composite at the edges.

Index Terms:RCC column, CFRP, Corner radii, wrapped.

I. INTRODUCTION

Over the period few years, there has been a worldwide increase in rehabilitation of deficient reinforced concrete (RC) structures by using some composite materials. One important application or technology for retrofitting the structurally deficientstructures is the use of carbon fibre reinforced polymer (CFRP) wrapping. The CFRP provides external confinement of RC columns when the capacity of existing structure is inadequate. RC columns need to be laterally confined under heavy loadto ensure large deformation before failure and to provide an adequate load carrying capacity.

Previous studies have shown that confinement will increase the ductility and strength of material.Concrete restricted by these composite materials gives high strength and less ductility. Now-a-days, the materials composed by high stiffness and strength to weight ratios, non-corrodibility, have adopted as advanced solutions for repairing and rehabilitation of existing structural civil engineering.

Carbon fiber reinforced polymer (CFRP), are uni-directional forthe composite materials that are externally retrofitted to bonding concrete. The epoxy are used as bonding resins. Carbon fiber reinforced polymers are effectivefor the concrete columns that are applied in external wrapping [2]. The advanced reinforcing technique is used for reinforcing structurally deficient in structures of civil engineering. Minimal time and labor are the affective advantages of external reinforced steel straps in CFRP which shows ease in in-site implementation.

The exploratory investigation results that are gotten for the segment are talked about in this paper. Regarding load conveying limit and strains, acquired from tests on medium scale basically harmed square cross-sectional solid segments remotely strengthened with carbon fiber composite [3]. The parameters considered is providing different corner radii like 5mm (minimum),20mm(equal to clear cover)for structurally damaged square cross-sectional medium scale columns. Only one layer of wrapping is maintained for each column of different corner radii. A comparison is made between the ultimate strengths and strains of columns of different corner radii [1] with control specimen before and after wrapping with CFRP.

II. RESEARCH SIGNIFICANCE

The present paper manages the investigation of exploratory outcomes, regarding load conveying limit and strains, acquired from tests on medium scale fundamentally harmed square cross-sectional solid segments remotely strengthened with carbon fiber composite.

III. PROPERTIES OF MATERIALS

A. Cement

The concrete utilized in this investigation is Ordinary Portland Cement (OPC) of 53 grade. The properties of concrete are affirming to IS 12269-1987 determinations.

B. Fine aggregate

Fine aggregate which is used in this study islocally available and it confirms to IS specifications. The properties are shown in Table I.

Table I: Physical properties

S.No.	Property	Result
1	Specific gravity	2.56
2	Water absorption	0.40%

C. Coarse aggregate

Coarse total of ostensible size 20mm and 10mm, got from the nearby quarry affirming to IS particulars. The properties of coarse total are appeared Table II.

Table II: Physical properties

S.No.	Property	Result
1	Specific gravity	2.67
2	Water absorption	0.40%

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D. Water

The water utilized for throwing and restoring of solid test examples was free of acids, natural issue, suspended solids and contaminations which when present can unfavorably influence the quality of cement.

E. CFRP Sheet

Nature of CFRP utilized in present examination were uni-directional in nature. The sap framework used to bond the Carbon textures over the segments is an epoxy sap made of two sections, tar and hardener. The properties of CFRP sheet is given in Table III.

Table III: Properties of CFRP sheet given by the seller

Property	Details
Primary fiber direction	Uni-direction
Weight	230 gsm
Tensile strength	4900MPa
Elastic modulus	235000MPa
elongation	1.70%
Density	1.8g/cc
Nominal fiber Thickness	0.128mm

Fig. 1 shows that the Uniaxial CFRP that are used for the experimental work which are brought from Indian Mart.

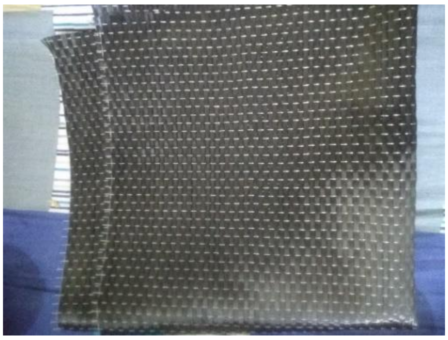

Fig.1 : Uniaxial CFRP

F. Epoxy Resin

Epoxy is a hardening agent which works to cure it into very strong adhesive. CFRP sheets are bonded by using epoxy adhesive. Fig 2 to shows Araldite LY556 and hardener HY951 mix proportion 100gms:10gms.

Fig. 2: Epoxy Resin

IV. EXPERIMENTAL PROGRAMME

A. Concrete Mix Proportion

All columns are casted by concrete of M20 grade. Mix design selected were in the ratio as Water: Cement: Sand: Coarse Aggregate, 0.50: 1 : 1.8: 3.1, respectively. Table IV shows the amount of ingredients that are used for the experimental work.

Table IV: Proportion of ingredients used for 1m^3.

S. No	Ingredients	Quantity (kg/m^3)
A	Cement	378
B	Sand	719
C	20 mm down size aggregate	1238
D	Water in liters	189

B. Test specimens

Dimensional details of RC columns,Notations,number of wraps,varying corner radii considered are presented in Table V.

Nomenclature

R	Corner radius provided
C0R0	Control specimen
C1R0	Retrofitted column wrapped with single layer of CFRP
C1R1	Retrofitted column wrapped with single layer of CFRP and providing 5mm corner radii
C1R1	Retrofitted column wrapped with single layer of CFRP and providing 20mm corner radii

Table V: Details of square RC columns

Column specimens	Column Notation	Cross-section (mm^2)	Height (mm)	R (mm)	No. of wraps	No. of columns
Column-1	C0R0	150 X 150	1500	0	0	1
Column-2	C1R0	150 X 150	1500	0	1	1
Column-3	C1R1	150 X 150	1500	5	1	1
Column-4	C1R2	150 X 150	1500	20	1	1
					Total	4

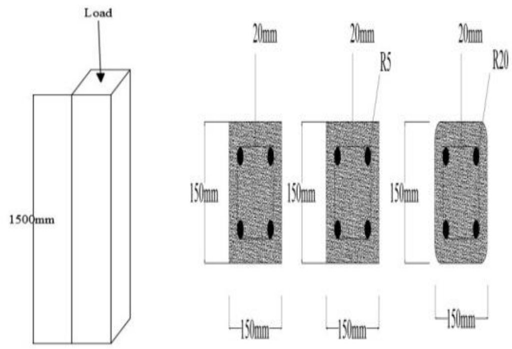

Fig .3: Column specimens with varying corner radii

C. Casting of columns:

4columns of cross-section 150 mm x 150mm square columns of height 1500 mm without corner radius have been cast respectively. Concrete is prepared in the concrete mixture machine as per proportions given in Table IV. The columns are reinforced with 4 bars of12 mm diameter TMT-500 bars as main reinforcement and 8 mm diameter ties are provided as shear reinforcement spaced at 150 mm c/c as medium scale RC column, designed based on IS:456.Casted

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columns are cured in normal water(saline less) for 28 days completely. Extra shear reinforcement is provided at the ends of column to avoid rupture of concrete at ends as it is not advised failure happens at ends. Reinforcement provided were two stirrups of same cross section of 5mm span of the two corners of main reinforcement as shown below.

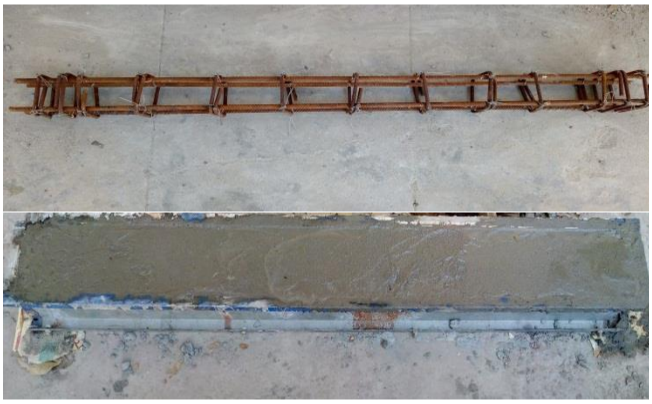

Fig.4: Mould of specified dimensions and reinforcement details.

D. Preparing the specimens:

The 3 casted column are made fail in loading frame of 2000kn capacityup to where slight cracks are visible in columns. Then the corners are shaped as desired as per the corner radii. First column is provided with minimum corner radii of 5mm, Second column is provided with corner radii equal to that of clear cover i.e., 20 mm. Third column is kept undisturbed without providing any corner radii.

E. Retrofitting:

The epoxy was hand-mixed thoroughly for 5 minutes before useat least. The epoxy is two stage system (PrimerandSaturant) consisting ofhardenerandresin. This epoxy resin is used for retrofitting the cracked columns. Resin is applied to cracks in order to fill the cracks with epoxy resin. As it is a good binder it creates a good bond between the crack. Same resin is used for wrapping the CFRP.

F. CFRP Wrapping:

The CFRP Sheets were applied directly onto the surface of the specimens using this epoxy resin. Overlapof 75 mm is maintained to ensure the development of tensile strength of full compositethroughout the column. Installers are also used to avoid any voids formation while wrapping.

V. TEST PROCEDURE

The column specimens are tested on a 2000kN capacity loading frame under uni-axial compressive load. Steel plates were used as column caps to ensure parallel surface to columns which distribute the load uniformly with minimum eccentricity. Loading rate of loading frame is maintained at 10kN and this rate is maintained constant up to cracks appeared on surface of the column specimen. Load at which failure occurs is shown in the Table VI.

Table VI: Load at which cracks formed for different columns

S.No.	Column notation	Load at which little cracks formed (kN)	Avg. Load (kN)
1	C0R0	--	473
2	C1R0	472	
3	C1R1	474	
4	C1R2	473	

The 3 columns with cracks are provided with 0mm, 5mm, 20mm corner radii. Then these columns are retrofitted with CFRP. The adhesive used for binding is epoxy resin.

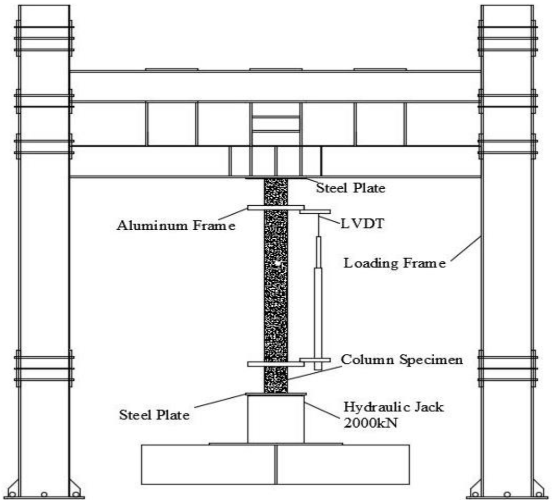

Fig .5: Loading frame with test specimen.

VI. RESULTS AND DISCUSSION

Axial load

Extreme load at which the considerable ultimate failure load is noted and analysed over unconfined in the Table VII.

Table VII: Experimental Results

S.No.	Column Notation	Ultimate load	% Increase of ultimate load over unconfined
1	C0R0	595	--
2	C1R0	743	25%
3	C1R1	862	45%
4	C1R2	1065	79%

It has been observedthat the ultimate load carrying capacity of columns from C0R0 to C1R2 was increased rapidly. The wrapped columns C1R0,C1R1, and C1R2 gained more Ultimate load when compared with unwrapped column. It was also been evident that amount of corner radius provided played major role in gaining the ultimate load capacity of wrapped columns. Percentage increase in ultimate load of confined column over unconfined is 25%. Percentage increase in ultimate load of columns provided with 5mm(minimum) and 20mm(equal to nominal cover)over unconfined is 45% and 79% respectively.it also evident that from Table VII Ultimate load of C1R1 increased by 16% over C1R1. Similarly 24% is increased by

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C1R2 over C1R1. Higher load carrying capacity also depends on corner radii of RC columns. RC column provided with 20 mm corner radius had gained 24% more ultimate load as compared with RC column provided with 5 mm corner radius. This behavior of RC columns clearly explains the importance of corner radius for enhancing load baring capacity of column and RC column confined with single layer of CFRP provided with corner radius equal to the nominal cover gives the best load carrying capacity over the other.

VII. CONCLUSIONS

Based on the experimental results, the following conclusions are drawn

- In this manner it is obviously clear from the above correlation that higher load is obtained of a singly wrapped column is achieved when beam is provided with a corner radii equal to nominal cover.
- RC column provided with 20 mm corner radius had gained 24% more ultimate load as compared with RC column provided with 5 mm corner radius.
- The columns provided with of 20 mm corner radius performed better as compared to the column provided with 5 mm corner radius.
- It is clearly proved the amount of corner radii provided for columns plays main role in rupture of CFRP and ultimate load carrying capacity of columns wrapped with CFRP.

RC columns which are structurally deficit in existing building are very Retrofitted with the help of CFRP. Load carrying capacity of Square cross-sectional columnsis very well enhanced by providing the corner radius to edges of square column. Hence CFRP wrapping with corner radii is strongly recommended for retrofitting of structural elements.

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