Behavior of Reinforced Concrete columns Wrapped by CFRP Under Eccentric and Concentric Loading

K. Ganesh, I. Siva Kishore, K. Shyam Chamberlin, K. J Brahma Chari

Abstract: ***In this era of modern science and technology, the architectural science also took a new leap into show case the avant-garde architectural marvels of the architectural experts that pose never ending challenges to the structural engineers and designers. The design engineers have to deal with new member geometrics, member materials and all possible matrix of such combinations of materials, geometrics and design methods to meet the needs of modern man and architecture. In this work, performance of a column of compound material (concrete and steel, RCC, CFRP) as a flexural column is studied with an eccentric and concentric loading and possible ways of improving the flexural (eccentrically loaded) column performance by using carbon fiber reinforced polymer is studied. 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 but different geometric shapes of the structural members have shown different flexural and tensile load sustaining capabilities due to shape and eccentricity effect. To overcome / minimize this limiting performance of a column as a flexural member, the CFRP is introduced in layers around the columns. The experiment is carried out on three groups of total of (6) columns. Each group consists of (2) columns, group-1 consists of (2) RCC columns without CFRP fabric, group-2 consists of (2) columns with confinement by CFRP fabric of one layer and group-3 comprises of (2) columns with confinement by CFRP fabric of two layers. Columns are tested under uniaxial eccentric and concentric loading, the results shows that the performance of the RCC columns, as a flexural column, wrapped by CFRP fabric has increased considerably and sustained the additional loads compared to unwrapped RC columns even on eccentric loading.***

Keywords: RC columns, CFRP fabric, wrapping, eccentric loading, uniaxial.

I. INTRODUCTION

Practically columns are not face concentric loads exactly, because it must be have minimum eccentricity i.e., 0.05D from [IS: 456-2000]. The eccentricity of loads are cause by alignment of beams, irregular structure and drawbacks of load distribution due to these reasons columns can undergo buckling failure or lateral moments and as usually sapling of material. In any way the eccentricity loads are two types one is purely uniaxial load and next one is biaxial load. Among these two in this paper describes about behavior of purely uniaxial load column by wrapping with CFRP and the cross section of the column is in uniaxial shape.

The uniaxial compression member failure in flexural mode or in tension zone by varying main reinforcement also [1]. The square reinforced concrete columns are wrapped by CFRP fabric, specimens performed with more load carrying capacity and higher ductility under large eccentric loading [2]. From this CFRP fabric has more ductility strength and the fabric has higher mechanical properties

Finally this paper shows the behavior of purely uniaxial shape column wrapped by CFRP fabric.

The columns are divided into three groups and each group has two columns named as 0C0, 0C50 and this pair is unwrapped with CFRP. The next group B is named as 1C0, 1C50 wrapped with one layer CFRP fabric and the following group C is 2C0, 2C50 wrapped with two layer CFRP fabric shown table [1].

Table 1: Description of layer and loading

Name of column	No. of CFRP layer	Point of loading
0C0 0C50	Zero Zero	Concentric Eccentricity 50
1C0 1C50	One layer One layer	Concentric Eccentricity 50
2C0 2C50	Two layer Two layer	Concentric Eccentricity 50

II. EXPERIMENTAL PROGRAMME:

A. Materials:

In this experiment M25 mix design concrete grade was used and mix design based on IS: 456 – 2000. For flexibility and strength purposed chosen the combination of coarse aggregate with 20mm and 10mm size with 60% and 40% respectively. Strength of concrete was tested by cubes of 150*150*150mm in compression and cylinders for tensile strength of M25 grade concrete.

Table 2: Strength testing of M25

STRENGTH of MODE	STRENGTH at 28DAYS
Compression	800 kN
Tensile	7 kN

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The other main material is Carbon Fiber Reinforced Polymer fabric, this is supplied by CFRP fabrics from Bombay. The thickness of fabric has 0.128mm and orientation of fabric is unidirectional. It is available in 0.5m width and length in roll form shown in fig 1.

Table 3: properties of CFRP

Tensile elastic modulus MPa	Tensile strength in MPa	Thickness in mm	% of Elongation
235000	4900	0.128	1.7

Fig 1. CFRP roll
source: currently used

For confinement purpose the epoxy was used between reinforced concrete columns and CFRP fabric. The ratio of RESIN and hardner is 1:1 Fig [2] with two coats on RC columns, now CFRP fabric wrap on concrete specimen in the process to avoid air voids roll the iron roller on fabric and epoxy again paste on wrapped CFRP fabric

For reinforcing steel the f_y 550 grade steel was used with 12mm diameter bars as main bars and for shear reinforcement as usually fy550 with 8mm dia bars are tied with longitudinal bars.

Fig 2. Epoxy
source: currently used

B. Dimensions of specimen or configuration:

For this experiment totally 6 columns are casted with above mentioned materials. The column dimensions are 1200×150×100mm. After casting these specimens are cured for 28days for testing.

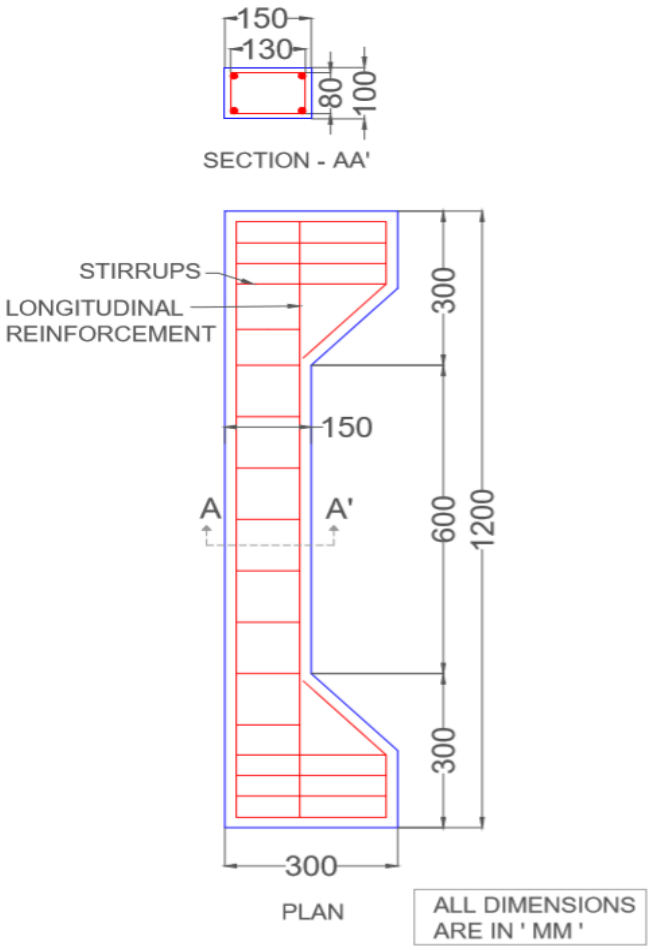


Fig 3. Reinforcement details
source: currently used

III. TESTING PROCEDURE

After 28days the specimens are tested under loading frame under concentric and eccentric loads.

A. Columns testing:

The uniaxial shaped reinforced concrete columns are tested under 200ton capacity loading frame in two methods axially and eccentrically with as per discussed as 3groups. Groups named as alphabetical series, each group consists 2 concrete columns one is concentric load test and eccentric load test, so totally for this study used 6 reinforced concrete columns.

The group A columns are unwrapped CFRP fabric due to for reference or conventional columns, these tested normally discussed axially and eccentrically. Group B columns are tested as group A but as per study used the CFRP fabric wrapped. The following group C as usually group B only but here 2layer fabric was used for to determine behavior of CFRP fabric wraps on uniaxial columns.

The wrapping procedure is given below.

B. CFRP wrapping:

First prepare the columns for wrapping of CARBON FIBER REINFORCED POLYMER fabric, for that remove the concrete surface for 3mm using hand cutting machine for significant confinement of CFRP and clean with sand paper, for clear visible and applying of epoxy on column surface.

After followed procedure apply 2coats of epoxy on reinforced concrete column surface for sufficient bonding but must not use single coat because confinement is very less between CFRP fabric and concrete surface. Then applied of epoxy, wrap the CFRP fabric as required model and lengths. In this way air bubbles are placed between CFRP fabric and concrete surface, here must clear the bubbles otherwise confinement is less so for that used laminate roller. Roll the roller on fabric and again coat the epoxy on CFRP fabric for sufficient bonding between concrete surface and CARBON FIBER REINFORCED POLYMER fabric. In this way significant confinement placed in concrete surface and fabric.

As per this study in group C used 2layer CFRP so, for this two more epoxy coats are applied on first layer CFRP fabric after some time of first layer applied, then immediately wrap the second layer fabric on that followed fabric layer and as usually again coat epoxy on second layer for sufficient confinement between fabrics in fig 4.

C. Observations of columns testing:

Column failures are observed by visually and for displacement observation used LVDT (Linear Variable Differential Transformer). In unwrapped columns observed the mild cracks with entire column and after some loading point concrete material spalled of concentric loading point at top and bottom. While in eccentric test column experienced crushed and lateral displaced placed at middle Fig [6].

In group B columns failure like group A only but crossed the limit of group A column strength, and it maintain some significant performance, then appear the collapsed sounds and CFRP peeling sound. But cracks are not observed due to fabric, after at some point CFRP shows the tensile nature and fabric teared with some concrete material in concentric test.

At the time of eccentric point column displaced laterally at middle of the column and suddenly bursted CFRP fabric with peeling sounds.

Following group C failures observed like group B only but in group C shown the CFRP bears huge load than expected, the two layer fabric is said as significant words in load carrying capacity.

Fig 4. Reinforced concrete columns Wrapped with CFRP
source: currently used

The final ultimate load carried capacities and deflections are shown table [4]. Every specimen carries significant load but greater variation in unwrapped and wrapped columns, simultaneously axial load and eccentric load conditions.

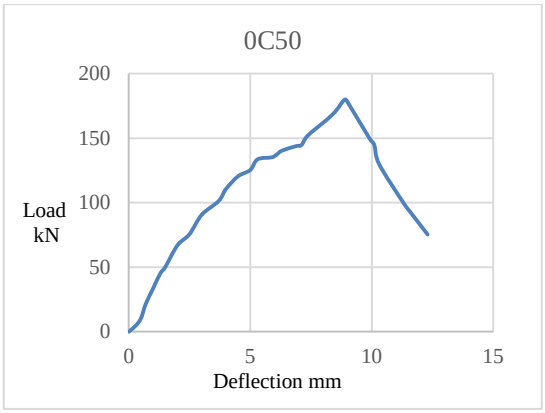
D. Results

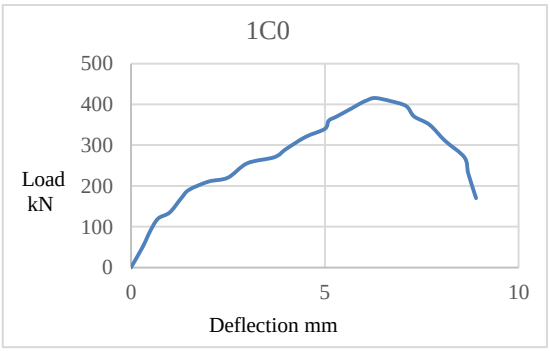
Table 3: concrete columns tested values.

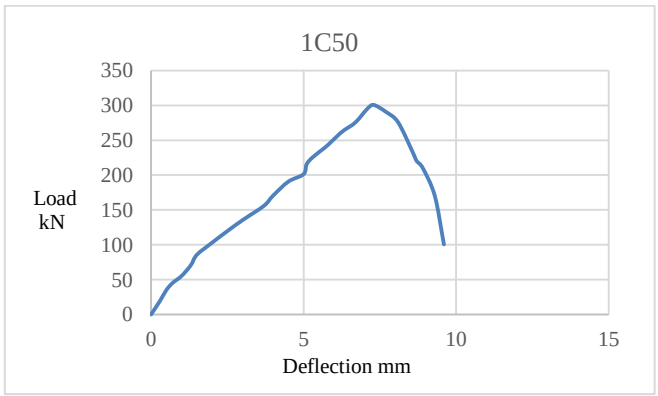
Type of section	Ultimate load in kN	Axial displacement in mm	Eccentric displacement in mm
0C0	257	5	
0C50	180.30	-	8.9
1C0	415.60	6.3	
1C50	300.60	-	7.3
2C0	560	8.7	
2C50	350.60	-	12.3

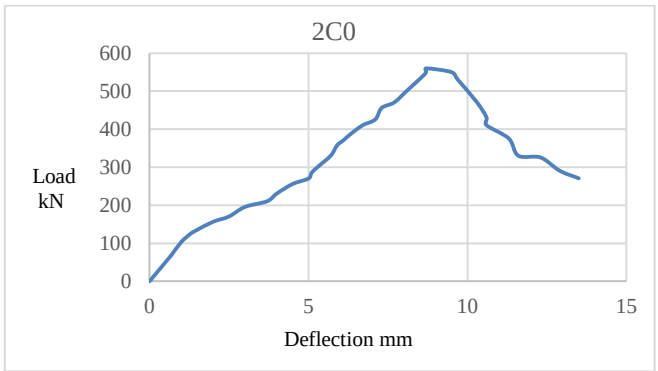
IV. BEHAVIOR OF SPECIMENS:

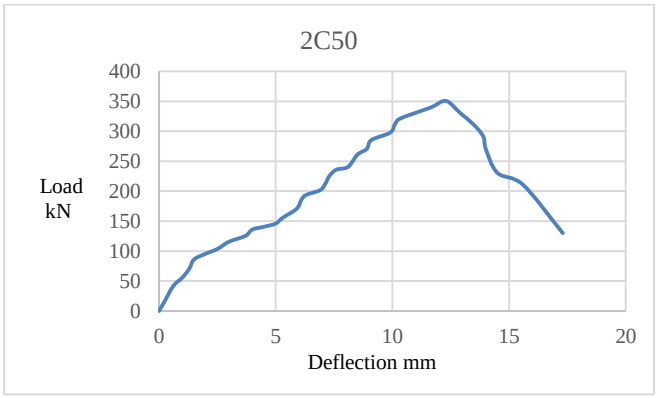
Behavior of the columns are observed in way of load vs deflection combination as expressed in graphical representation also as shown below Figures. 2c0 specimen graph shows the highest peak among remaining graphs so it gives that CFRP behaves an impact result on RCC member and the graph 2c50 eccentrically also CFRP shows marvel impact it maintained more than 75% of conventional strength limit. The load versus deflection curves are also shown as variations between point of loading with no. of CFRP layers.

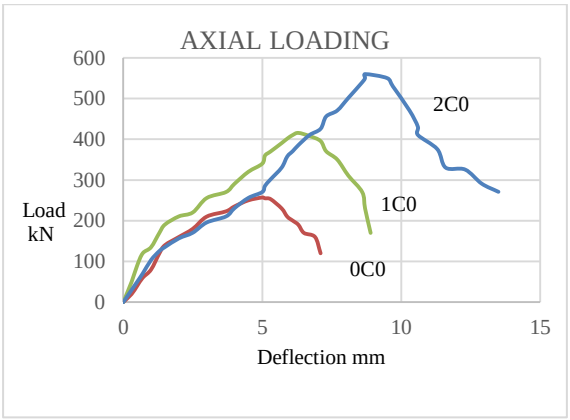


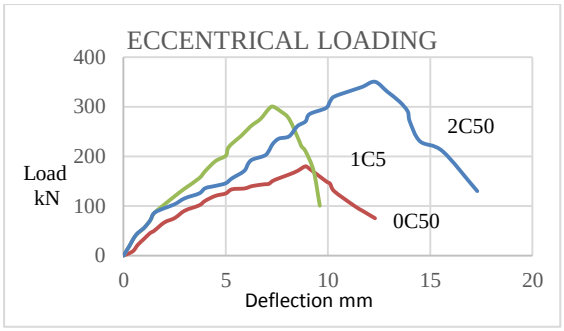












V. FAILURE OF SPECIMENS

Fig 5: Tested axially of conventional Specimen 0c0

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Fig 6: Tested eccentrically of conventional Specimen 0c50

Fig 7: Tested concentrically of one layer CFRP specimen 1c0

Fig 8: Tested under eccentrically one layer CFRP 1C50

Fig 9: concentrically loaded two layer CFRP Specimen 2c0

Fig 10: Eccentrically loaded two layer CFRP Specimen 2c50

VI. CONCLUSION

From this study concluded the CFRP wrap bears huge load carrying capacity in reinforced concrete components, as per test results CFRP wrapped columns performed well than conventional columns even in eccentrical loading. Group C shown better than group B load carrying strength in both point of view axially and eccentric in uniaxial reinforced concrete columns. So, CFRP has effective impact performed.

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