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Behaviour of Reinforced Concrete Beam Column Joint Retrofitted With Carbon Fiber Reinforced Polymer Sheets

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Abstract - *This paper investigates the behaviour of reinforced concrete beam column joint retrofitted with carbon fiber reinforced polymer (CFRP) sheets under reverse cyclic loading. Beam column joints, being the lateral and vertical load resisting members in reinforced concrete structures are particularly vulnerable to failures during earthquakes. The results show that the reinforced concrete beam column joint retrofitted with CFRP sheets can increase their load carrying capacity and energy dissipation capacity.*

Key Words: Carbon fiber reinforced polymer (CFRP), Beam-column joints, Reverse cyclic loading, near surface mounted

1. INTRODUCTION

Beam column joints are the most vulnerable portion in a reinforced concrete frame subjected to seismic forces. Fiber Reinforced polymer (FRP) composites are used nowadays for retrofitting of the beam column joints in order to avoid demolition and subsequent rebuilding of RC structures. Carbon fiber reinforced polymer (CFRP) is a composite materiel made up of various carbon fibers and thermosetting resins can be effectively used as the confinement for beam column joints by using wrapping techniques. Thus the seismic performance of RC beam column joints can be improved. The techniques of using fiber sheets for strengthen the beam column joints have a number of favorable characteristics such as ease to install, immunity to corrosion and high strength.

1.1 Objectives

The main objective of this study is to investigate about the strength and serviceability of the CFRP retrofitted beam column joint.

- To study the retrofitting of beam column joint by changing bond length of CFRP.
- To study the retrofitting schemes for severely damaged beam, column and joint by using near surface mounted method.

2. MODELLING

Modelling of the beam column joint retrofitted with CFRP sheets was done using ANSYS WORKBENCH 16.1.

2.1 Control specimen

The specimen had reinforcement details as per code IS 456:2000 . It had an extruded beam of 900 mm length and cross-sectional dimensions of 200 x 300 mm. This beam was connected to a column at its mid-height point. The cross-section of the column was 200 x 300 mm. The total length of the columns was 2300 mm divided into two equal parts, lower part and upper part. The upper and lower reinforcement of the beam in addition to the main longitudinal steel reinforcement of the column were made from Fe 415 steel .

The main steel reinforcement of the beam was three bars of 16 mm diameter, while the secondary steel reinforcement was two bars of 12 mm diameter. On the other hand, the column was reinforced with four bars of 16 mm diameter at each corner of the column cross section. The stirrups for beam were steel bars of 8 mm diameter and spaced every 100 mm for the beam. The ties for column were steel bars of 8mm diameter and spaced every 150 mm for the column. Concrete of grade 30 MPa is provided. Table 1 shows the material properties of steel and concrete. Figure 1 shows the dimensions and reinforcement detailing for the control specimen. Figure 2 shows the model of control specimen.

Table -1: Material properties of steel and concrete

Property	Steel	Concrete
Young's modulus	$2x10^5$ MPa	27386 MPa
Yield strength	415 MPa	3.83 MPa
Poisson's ratio	0.3	0.15

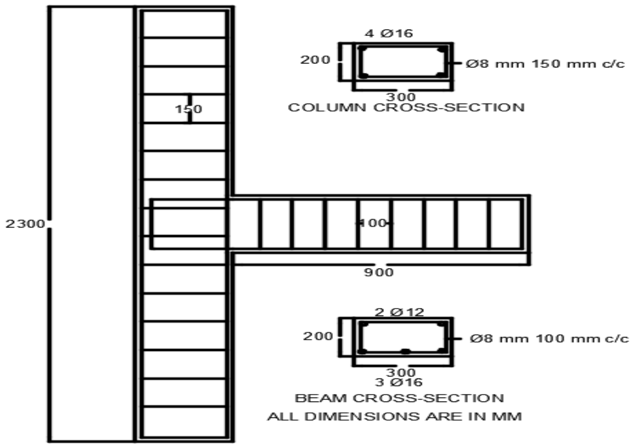

Fig – 1: Dimensions and reinforcement detailing for the control specimen

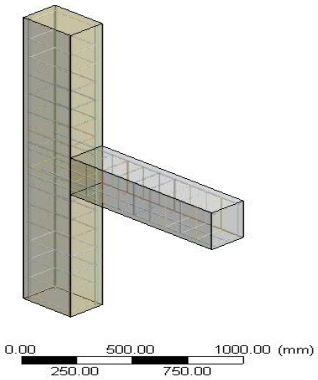

Fig – 2: Control specimen

2.2 Finite element model of reinforced concrete beam column joint retrofitted with CFRP sheets using near surface mounted method

The control specimen is analysed using ANSYS WORKBENCH 16.1. Here reverse cyclic loading was applied at the free end of the cantilever beam and the failure load is noted. The specimen for retrofitting loaded up to 75% of this failure load. After this they were retrofitted with CFRP sheets. The properties of steel and concrete used for the specimen are same as that of control specimen. Parameters considered for modelling of the beam column joint retrofitted with CFRP sheets are the bond length of CFRP in joint region only and both beam and column.

For the wrapping of CFRP sheets on the cover of beam column joint near surface mounted method was used. In this method grooves were cut on the cover of the beam column joint. Use brushes and pressurized air to remove debris in the grooves. Epoxy paste is inserted in to the groove as binder. Two numbers of 200 mm long CFRP bars are pushed in to the binder materials on the both face of beam column joint. Finally remaining part of the groove is filled with the epoxy paste.

Table -2: Description of models

BC	Control specimen
NB$_0$C$_0$	Specimen retrofitted with CFRP in joint region only
NB$_{100}$C$_{100}$	Specimen retrofitted with CFRP for both beam and column by bond length 100 mm
NB$_{200}$C$_{200}$	Specimen retrofitted with CFRP for both beam and column by bond length 200mm

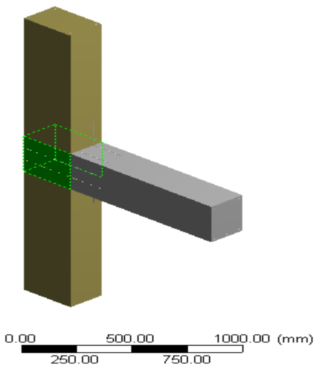

Fig – 3: Specimen retrofitted with CFRP in joint region only

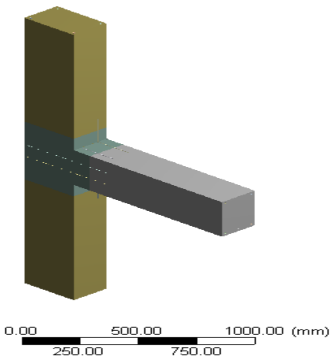

Fig – 4: Specimen retrofitted with CFRP for both beam and column by bond length 100 mm

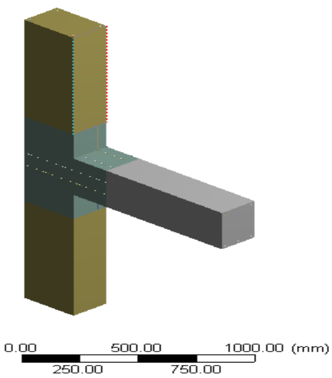

Fig – 5: Specimen retrofitted with CFRP for both beam and column by bond length 200 mm

3. RESULTS AND DISCUSSION

The behaviour of reinforced concrete beam column joint retrofitted with CFRP sheets using near surface mounted method were analysed using finite element analysis in ANSYS WORKBENCH 16.1.

3.1 Hysteresis loops

Chart 1-4 shows the hysteresis loops obtained for the specimens after the analysis.

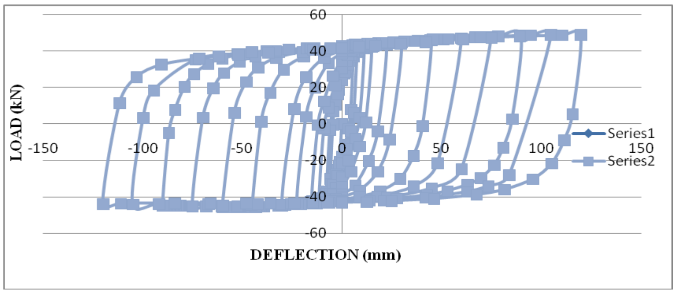

Chart – 1: Hysteresis curves for BC

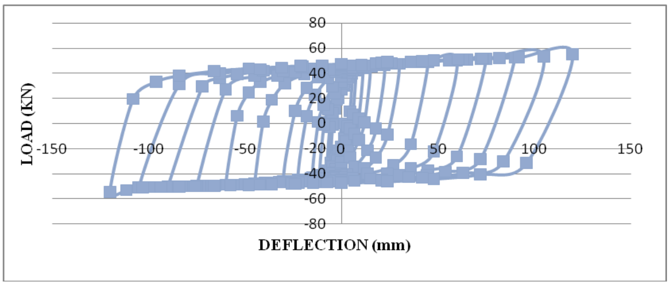

Chart – 2: Hysteresis curves for NB_0C_0

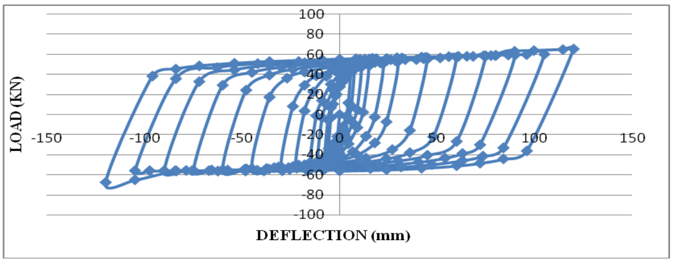

Chart – 3: Hysteresis curves for $NB_{100}C_{100}$

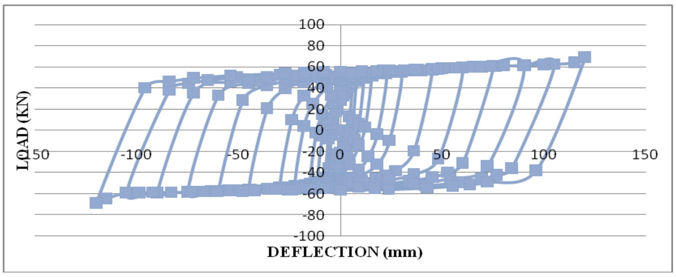

Chart – 4: Hysteresis curves for $NB_{200}C_{200}$

From the above Charts the energy dissipation capacities of beam column joint specimen were determined.

3.2 Energy dissipation capacity

As a measure of the dissipated energy of the specimens, the area under the load displacement curves for all cycles were computed and called as energy that could be dissipated by the specimens before the specimen lost its stability. In the evaluation of earthquake resistance, energy dissipation capacity of a structure is traditionally associated with the shape of the load displacement hysteretic loops. Table 3 shows the analytical results of energy dissipation capacity of models. . It was observed that maximum energy dissipation capacities of $NB_{200}C_{200}$, $NB_{100}C_{100}$ and NB_0C_0 were increased by 52.58% ,42.34%and14.70% respectively when compared with control specimen. It can be seen that energy dissipation capacity of reinforced concrete beam column joint retrofitted with CFRP sheets for both beam and column by bond length 200 mm ($NB_{200}C_{200}$) increases about 52.58% as compared to the control specimen.

Table -3: Analytical results of energy dissipation capacity of models

Model	Energy dissipation capacity (kNm)	% increase
BC	84.47	-
NB_0C_0	96.89	14.70
$NB_{100}C_{100}$	120.24	42.34
$NB_{200}C_{200}$	128.89	52.58

3.3 Load vs deflection envelope curves

The deflection is a key parameter for determining load carrying capacity of reinforced concrete beam column joint. Table 4 shows the analysis results in the terms of load carrying capacity of reinforced concrete beam column joint retrofitted with CFRP sheets using near surface mounted method. Based on the analytical results, the ultimate load carrying capacity of reinforced concrete beam column joint retrofitted with CFRP sheets is found higher than that of control specimen as shown in Table 4. Chart 5 shows the load vs deflection envelope curves of models. From the graph it is clear that specimen retrofitted with CFRP sheets for both beam and column by bond length 200 mm ($NB_{200}C_{200}$) carried the maximum ultimate load as 64.71 % more compared to the control specimen.

Table -4: Analytical results of ultimate load of models

Model	Ultimate load (kN)			% Increase
	Downward direction	Upward direction	Average	
BC	48.96	45.54	47.35	-
NB_0C_0	54.58	55.23	54.90	16.19
$NB_{100}C_{100}$	72.87	73.56	73.21	54.94
$NB_{200}C_{200}$	76.77	78.89	77.83	64.71

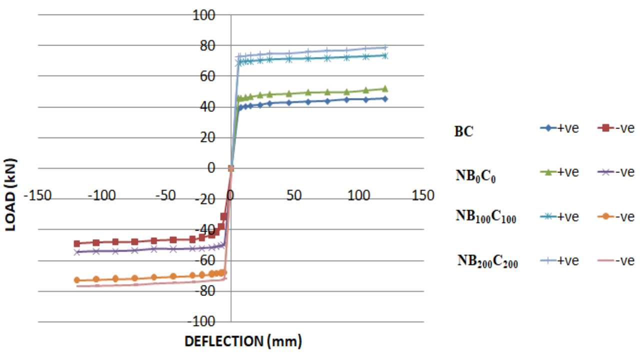

Chart – 5: Load vs deflection envelope curves of models

It was observed that maximum load carrying capacities of $NB_{200}C_{200}$, $NB_{100}C_{100}$ and NB_0C_0 were increased by 64.71% , 54.94 % and 16.19% respectively when compared with control specimen as shown in Table 4.

Figure 6-9 shows the deformed shape of all models.

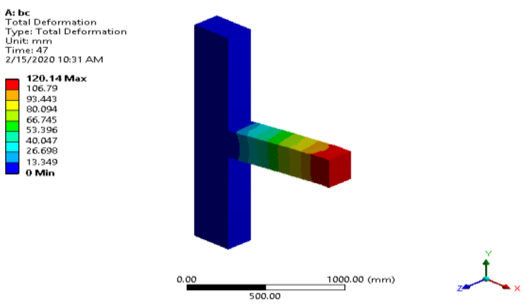

Fig – 6: Deformed shape of BC

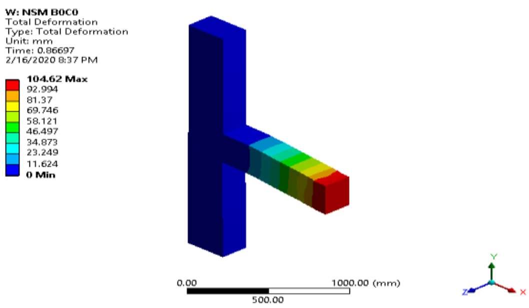

Fig – 7: Deformed shape of NB_0C_0

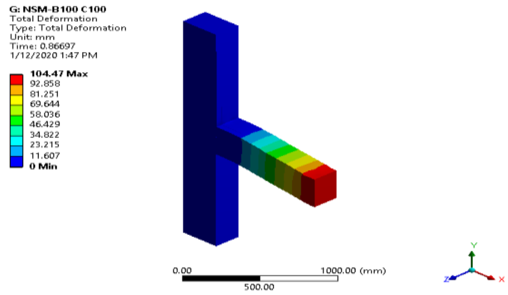

Fig – 8: Deformed shape of $NB_{100}C_{100}$

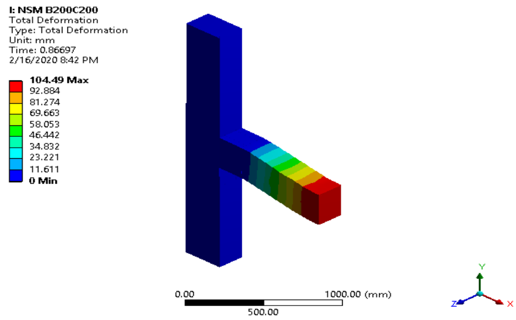

Fig – 9: Deformed shape of $NB_{200}C_{200}$

4. CONCLUSIONS

The following conclusions were obtained from the analysis carried out in this work.

- Specimen retrofitted with CFRP sheets for both beam and column by bond length 200 mm ($NB_{200}C_{200}$) has increased maximum energy dissipation capacity is 52.58 % when compared with the control specimen.
- Comparison between the load-deflection results obtained from ANSYS for control specimen and specimen retrofitted with CFRP sheets shows that the maximum ultimate load has increased for the specimen retrofitted with CFRP sheets for both beam and column by bond length 200 mm ($NB_{200}C_{200}$) is 64.71%.
- From the study, it can be concluded that retrofitting with CFRP sheets will increase the strength of the beam column joint specimen.

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