NUMERICAL STUDIES ON CFRP CONFINED REINFORCED CONCRETE BEAM-COLUMN JOINTS

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ABSTRACT: This paper presents an analytical investigation of Carbon Fibre Reinforced Polymer (CFRP) confined reinforced concrete exterior beam-column joints using finite element software ANSYS. Under the seismic loads, exterior beam column joint is one of the critical regions in the multi-storied building. In this paper, the results of analytical investigation of CFRP confined exterior beam-column joint subassemblies including the un-strengthened joints. The main aim was to improve the load carrying capacity for the CFRP confined beam-column joints. A comparative study has been carried out from the results of control specimens to that of confined specimens. The result shows that the confinement of CFRP joints significantly improved the strength and reduced its deformation when compared to the un-strengthened joints.

Keywords: **CFRP; Deflection; Exterior beam column joints; Energy absorption capacity; Load carrying capacity**

I. INTRODUCTION:

In RC buildings, the portions of columns that are common to beams at their intersection are called Beam-Column joints. When one beam frames into the vertical face of a column in the perpendicular direction is called an exterior joint. Beam-column joints are recognized as the critical and vulnerable zone of a Reinforced Concrete (RC) structure subjected to seismic loads. Under the action of seismic forces, beam-column joints are subjected to large shear stresses in the joint region. These shear stresses are a result of moments and shear forces of opposite signs on the member ends on either side of the joint core. The axial compression in the column and joint shear stresses result in principal tension and compression stresses that lead to diagonal cracking and/or crushing of concrete in the joint core. The two major failure modes at joints are Joint shear failure and End anchorage failure. To improve the load carrying capacity of this failure joint, it is essential to confine the beam-column joints with CFRP material. Static analysis was carried out to study the behaviour of CFRP confined reinforced concrete exterior beam-column joints.

II FE MODELING OF BEAM COLUMN JOINTS

ANSYS 16 software is used for modelling the specimen.

2.1 CONTROL SPECIMEN DETAILS

The control specimen was designated as CS1. The control specimen had reinforcement details as per code IS 456:2000 as shown in Figure. 1. This control specimen was confined with Carbon Fibre Reinforced Polymer sheet were designated as C1. The column had a cross-section of 200mm x 200mm with an overall length of 1500mm for the CS1, C1. The beam had a cross section of 200mm x 200mm with a cantilevered portion of length 600mm for the CS1, C1. The main reinforcement had yield strength of 415 MPa. The column portion was reinforced with 4 numbers of 12mm diameters and the beam portion was reinforced with 4 numbers of 16mm. The lateral ties in the column of the both specimens were 6mm diameter Fe250 bars with the spacing of 180mm c/c as per code IS 456:2000 and the beam had vertical stirrups of 6mm diameter with a spacing of120mmc/c.

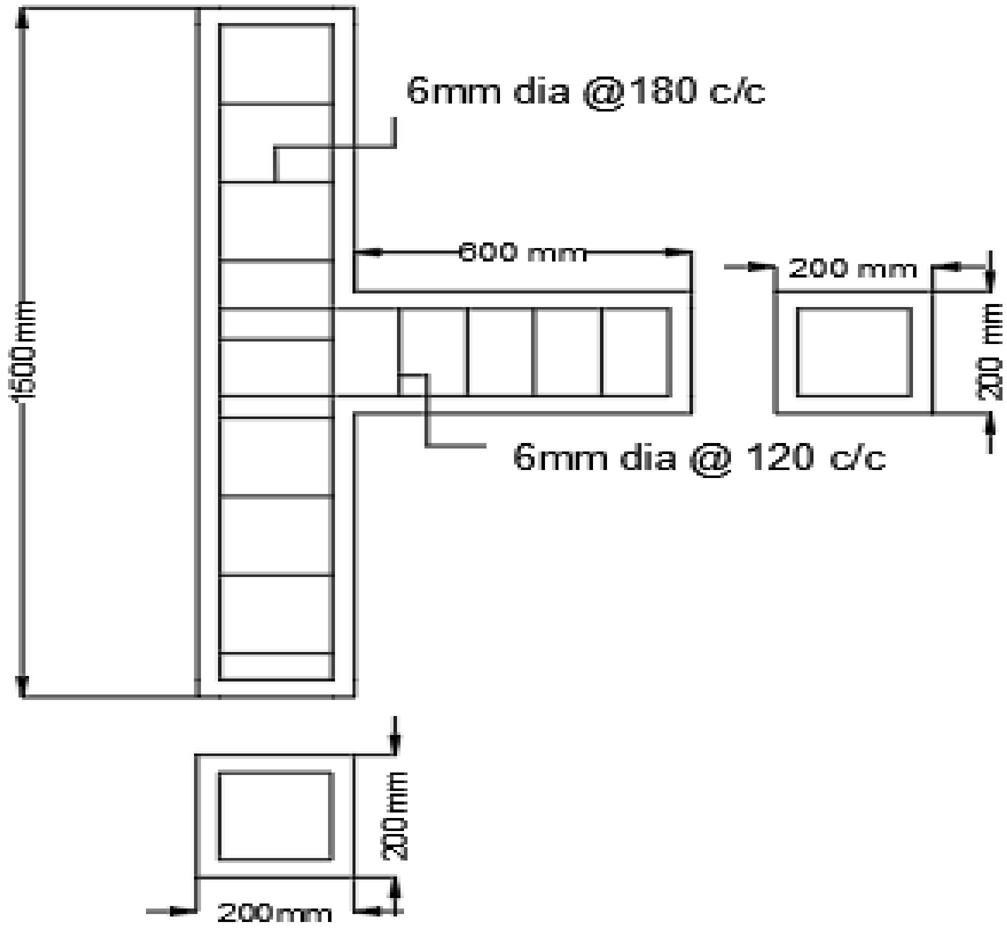

Figure 1: Reinforcement Detailing

2.2 ELEMENT TYPES USED FOR MODELLING

SOLID 65: This element is used to model concrete. This element has 8 nodes with three degrees of freedom at each node-translations in the nodal x, y, z directions. This element is capable of plastic deformation, cracking in three orthogonal directions and crushing.
LINK 180: This element is used to model the steel reinforcement. This element is a 3D spar element and it has two nodes with three degrees of freedom at each node – translations in the nodal x, y, z directions. This element is also capable of plastic deformation.
SOLID 185: This element is used to model the Fibre Reinforced Polymer (FRP). This element is defined by 8 nodes having three degrees of freedom at each node-translations in the nodal x, y, z directions. The element is capable of plasticity, hyper elasticity, stress stiffening, creep, large deflection, and large strain capabilities.
SOLID 185 is available in two forms: Homogeneous structural solid and layered structural solid. Layered structural solid is used to model the FRP. This element allows for up to 250 different material layers with different orientations and orthotropic material properties in each layer.

2.3 MATERIAL PROPERTIES FOR CONTROL SPECIMEN:

Parameters needed to define the material models for CS1 is listed in Table 1.

Table 1 Material Properties for Cs1

Material model no.	Element type	Material properties		
1	SOLID 65	LINEAR ISOTROPIC		
		EX		22360.68
		PRXY		0.2
		MULTILINEAR ISOTROPIC		
			STRAIN	STRESS
		1	0.0002683	6
		2	0.0006485	13
		3	0.0010286	17
		4	0.0014087	19
		5	0.0017889	20
		CONCRETE		
		ShrCf-Op		0.4
		ShrCf-Cl		0.8
		UnTensSt		3.13
		UnCompSt		-1
		HydroPrs		Default
		BiCompSt		Default
		UnTensSt		Default
		TenCrFac		Default
2	LINK 180	LINEAR ISOTROPIC		
		EX		200000
		PRXY		0.3
		BILINEAR ISOTROPIC		
		YIELD STRESS		415
		TANGENT MODULUS		0
3	LINK 180	LINEAR ISOTROPIC		
		EX		200000
		PRXY		0.3
		BILINEAR ISOTROPIC		
		YIELD STRESS		250
		TANGENT MODULUS		0

2.4 MODELLING OF BEAM-COLUMN JOINTS:

The joint is modelled as volume. The dimensions are shown in Table 2. The combined volumes created in ANSYS are shown in Figure. 2 and 3.

Table 2 Dimensions for Modelling

ANSYS	COLUMN (mm)		BEAM (mm)	
	VOLUME 1		VOLUME 2	
X-COORDINATES X1, X2	0	200	200	800
Y-COORDINATES Y1, Y2	0	1500	650	850
Z -COORDINATES Z1, Z2	0	200	0	200

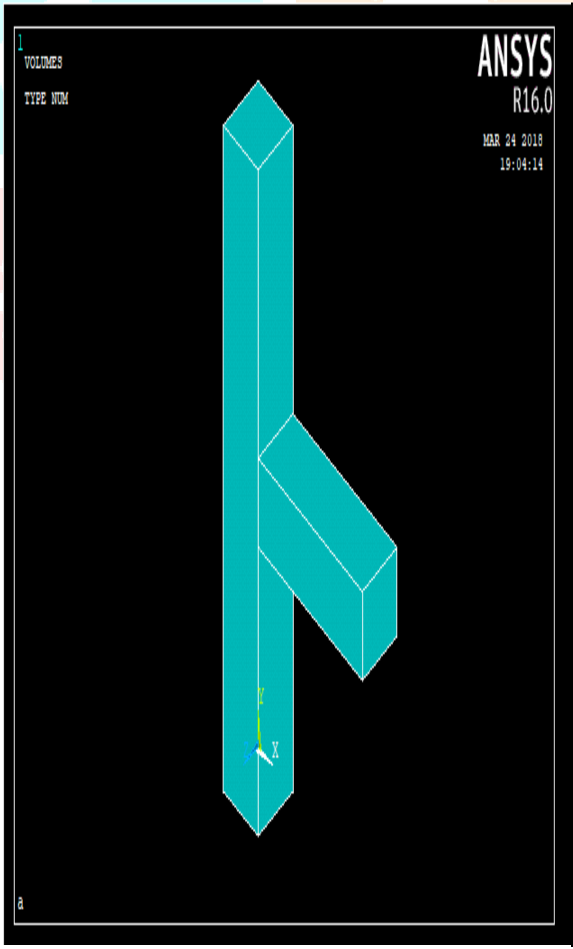

Figure 2: Volume Created for Cs1

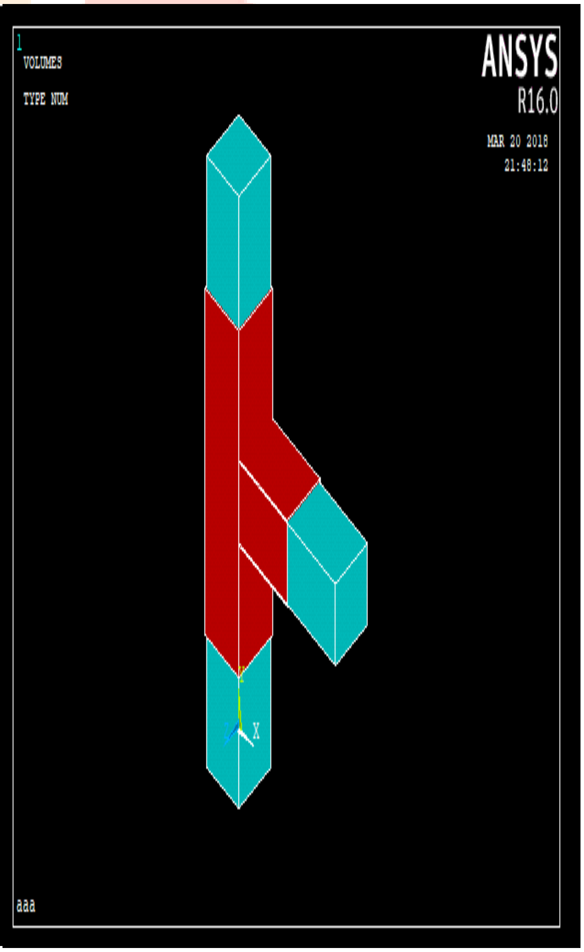

Figure 3: Volume Created for C1

2.5 MESHING:

To obtain good results from the SOLID65 element, the use of a rectangular mesh is recommended. Therefore, the mesh is set up such that the square or rectangular elements is created. The overall mesh of the control specimen and confined specimen created in ANSYS are shown in fig.4. The meshing of the reinforcement is a special case compared to the concrete volumes. Meshing of reinforcement is not needed because the individual elements are created by the mesh of concrete through the nodes.

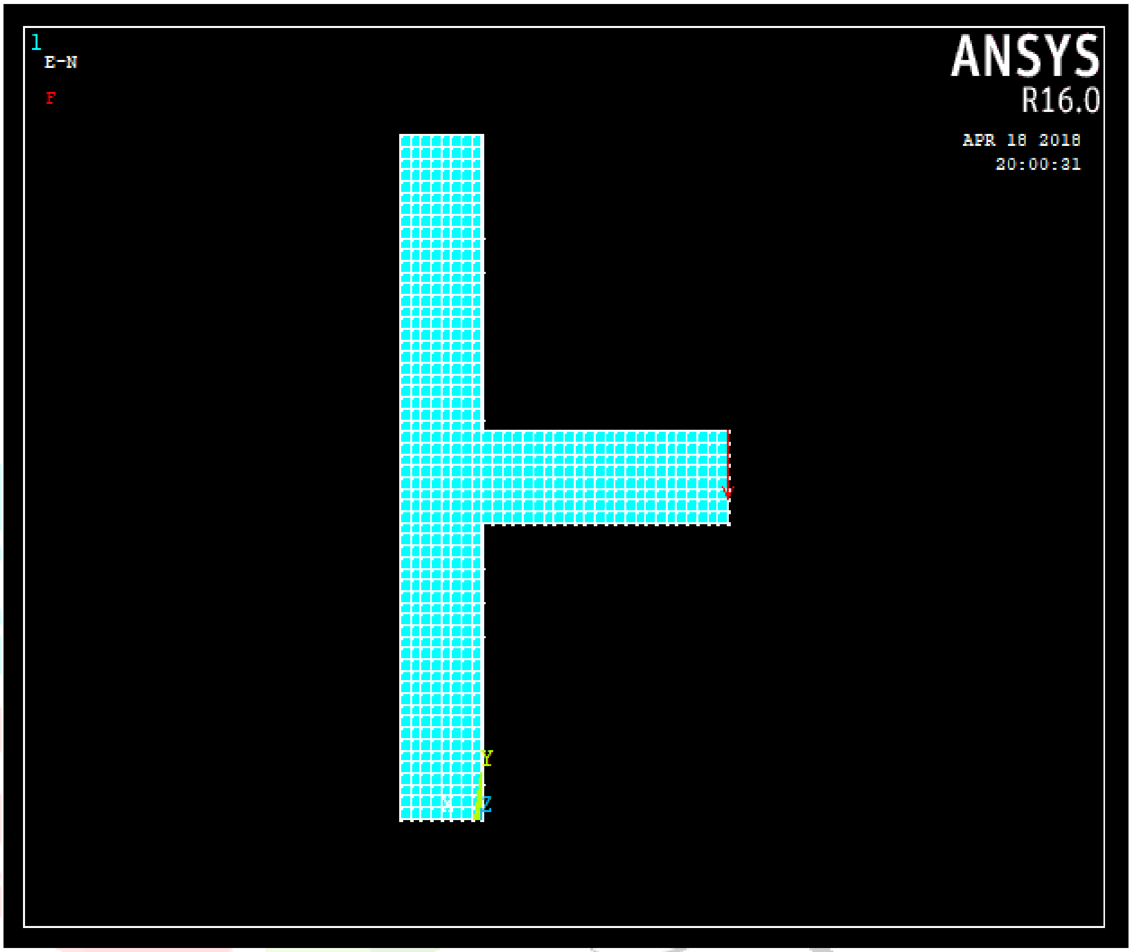

Figure 4: Mesh Created for Both Specimen

2.6 LOADS AND BOUNDARY CONDITIONS:

To get a unique solution, displacement boundary conditions are needed to constrain at the nodes (UX, UY, UZ) with the constant values as 0. The static force of 5kN was applied at the end of the free cantilevered beam for both the specimens. Force was increased in steps till a control load of 20kN.

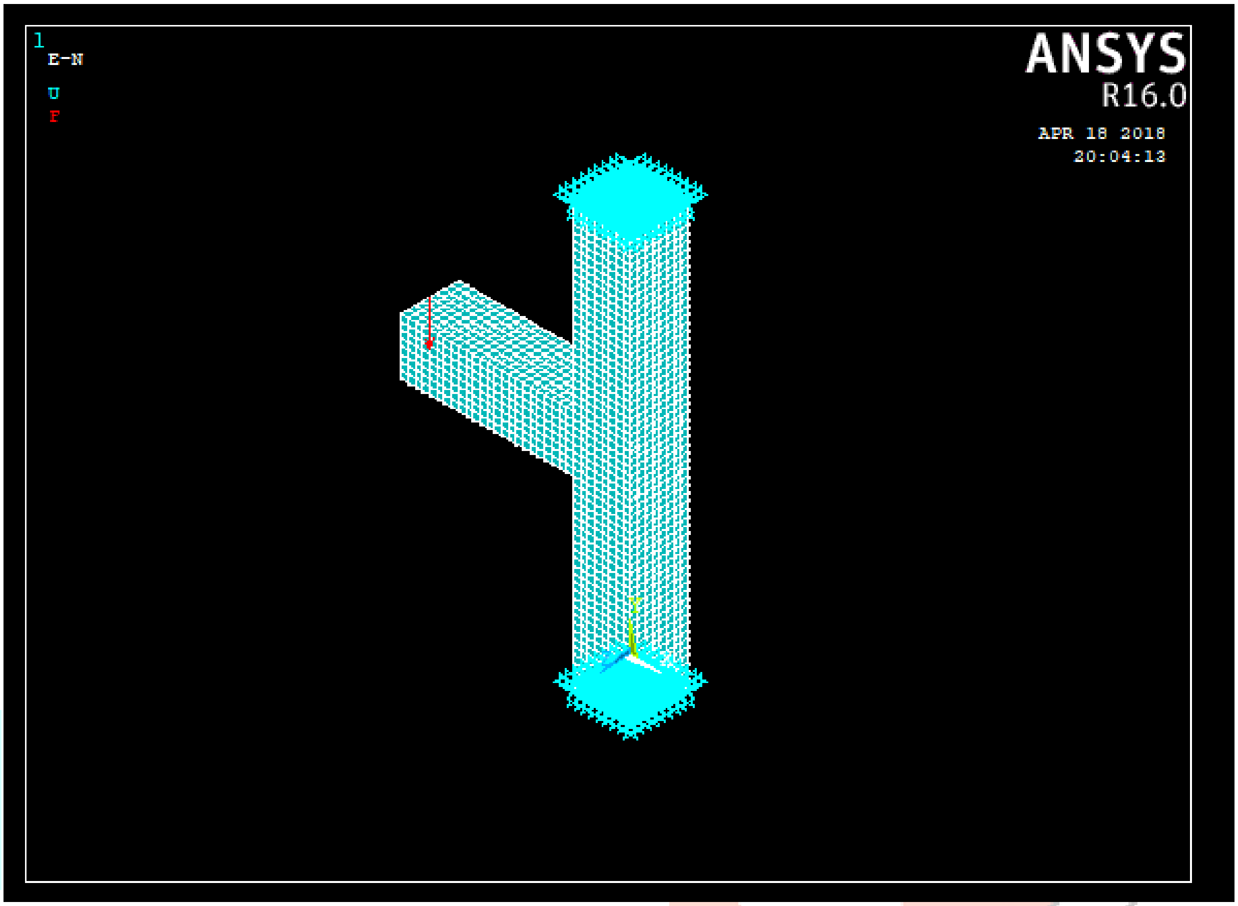

Figure 5: Loads and Boundary Conditions for The Specimen

III NON-LINEAR ANALYSIS OF THE JOINTS

The analysis was done for the un-strengthened joints and confined joints. This analysis was showed that the deflection at the free end of the beam. The deflection of CS1 was found to be 45.24mm under the load of 20kN and the deflection of C1 was found to be 9.33mm under the load of 20kN.

IV RESULTS AND DISCUSSIONS

In this the results of control specimen was compared with the confined specimen. The load deflection curve for the control specimen and confined specimen are shown in fig.6. The deflections at various load intervals of control specimen and confined specimen are listed in Table 3. Comparsion between the deflections and energy absorption capacity(E.A.C) for the specimens are listed in Table 4.

Table 3 Deflections of CS1 and C1

Specimen details		Deflection in mm		
	5 kN	10 kN	15 kN	20 kN
CS1	1.971	6.384	15.995	45.24
C1	1.789	3.6472	5.9856	9.33

Table 4 Deflections and energy absorption capacity of CS1 and C1

Specimen details	Deflection in mm (20 kN)	% reduction	E.A.C (kNmm)	% increase
CS1	45.24	---	151.96	---
C1	9.33	79.37	997.84	84.77

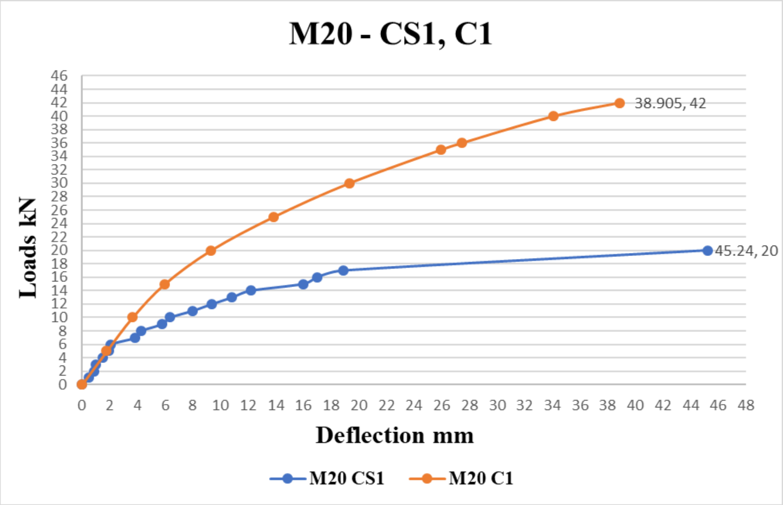

Figure 6: Load-Deflection Curve for Control and Confined Specimens

4.1 CONTROL SPECIMEN:

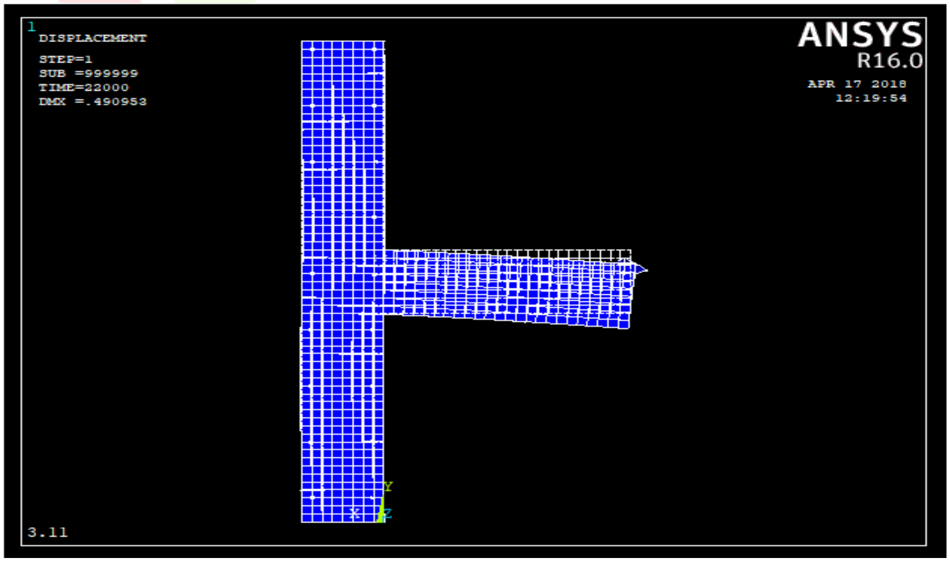

FIGURE 7: Deflected Shape of Control Specimen

4.2 CONFINED SPECIMEN:

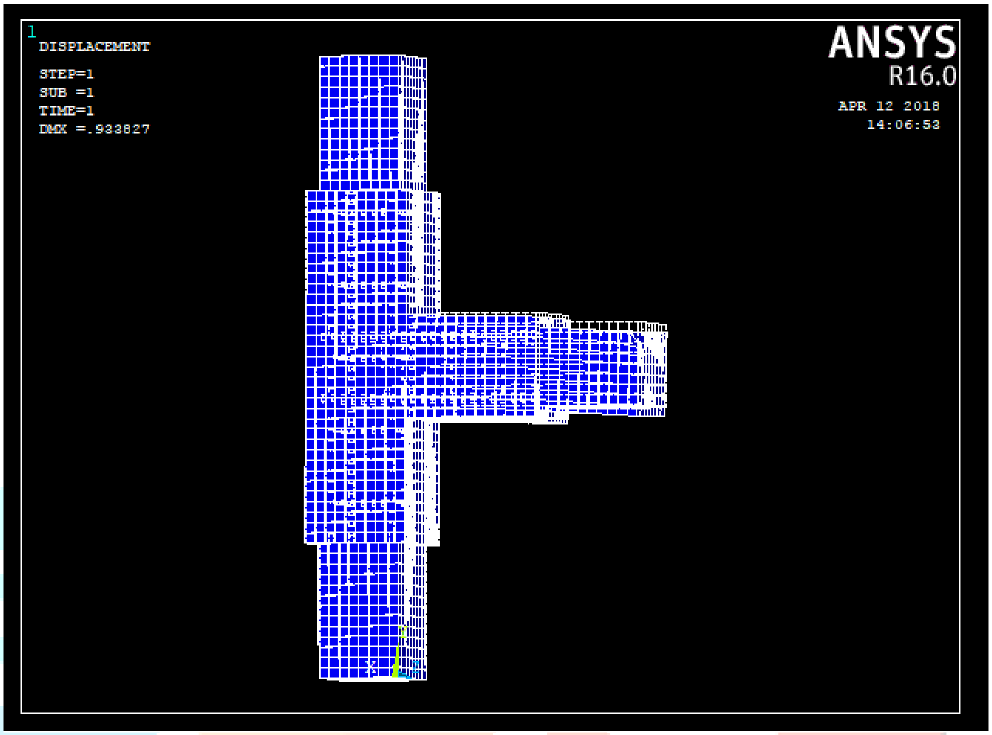

FIGURE 8: DEFLECTED SHAPE OF CONFINED SPECIMEN

5 CONCLUSIONS

The following conclusion can be stated based on the analysis of the control specimen and confined specimen:

1. The deflection of the confined CFRP beam column joints reduces the deflection about 79.37% when compared with the deflection of the control specimen.
2. The load-deflection result shows that the load carrying capacity has significantly increased for the confined specimen as compared to the control specimen.
3. The energy absorption capacity of confined beam column joints increased 84.77% when compared with the control specimen.
4. The higher values of load is associate with the lower deflections as compared to the control specimen.

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