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Analysis of Beam-Column Joint in a Prestressed Concrete Structure under Reverse Cyclic Loading

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Abstract: *The beam column joint in pre-stressed concrete member undergoes direct compression as well as bending compression and tension. This makes it vulnerable to failure. Concrete filled steel tubular structure is widely used in high-rise building. Generally, concrete filled steel tubular structure use the concrete inside and the steel tube wrapped around. This type of structure has some merits. Because of the complexity of the structure of joints, it can hardly be used consistent with prestressed concrete beam to form prestressed frame structure. This article use composite concrete column with core of concrete filled steel tube, put forward the structure form which is made up of prestressed concrete beam and composite concrete column with core of concrete filled steel tube. This paper includes the analysis of prestressed beam column joint with different tendon pattern also including the CFST column.*

Keywords: *ANSYS software, beam column joint, concrete-filled steel tube, hysteresis property, prestressed concrete structure.*

I. Introduction

In 1904, Freyssinet attempted to introduce permanently acting forces in concrete to resist the elastic forces developed under loads and this idea was later known as “Pre-stressing” .Pre-stressed concrete is basically concrete in which internal stresses of a suitable magnitude and distribution are induced so that the stresses resulting from external loads are counteracted to a desired degree .Concrete-filled steel tube (CFST) member is widely used for building, bridge and foundation structures because of its excellent performance. When a CFST member is subjected to axial loads, the filling concrete is confined by the steel tube, resulting in a tri-axial state of compression that improves its strength, stiffness and ductility. However, the cracking of concrete in tension zone would decrease this enhancement when the CFST member is subjected to flexure, especially when it is used as a major flexural member with large-scale section in bridges. Various studies are reviewed on the analysis of pre-stressed concrete structural members and after going through the existing literature on analysis of pre-stressed concrete element using FEM it is found that not many studies are available on analysis of beam to column connection.

The objectives of the study are to analyse behaviour of pre-stressed concrete beam column joint using finite element method, To find the hysteresis property of prestressed beam column joint, Compare the results of convensional beam column joint with prestressed beam column joint and prestressed beam –CFST column joint for different tendon pattern, To find out which configuration for joint is more efficient.

II. Literature Review

An analytical model is compared with a full scale hybrid frame connection specimen by Faur et al., 2012 that has been tested to a displacement controlled cyclic loading sequence. A full scale specimen consisting in an interior beam-column joint was tested to a displacement .The results show that the numerical model is unable to represent very accurate the unloading branches of the envelope hysteresis curves and, as a consequence, the self-centering ability is significantly overestimated. Pragya Soni et al. 2017 concluded after going through the existing literature on analysis of pre-stressed concrete element using FEM, not many studies is available on analysis of beam-to-column connection. As pre-stressing of beam column connection warrants knowledge of specific state of stress in the absence of this pre-stressing shall be erroneously executed. Hence, this study aims at critically analyzing the beam-column connection using FEM by application of suitable software tool like ANSYS, STADD-Pro or MIDAS. Varghese et al., 2012 presented a study of pre-stressed beams using finite element analysis to understand the response of prestressed concrete beams due to transverse loading. Structural static properties such as deflection and stress distribution of rectangular pre-stressed concrete beam were analysed analytically and by finite element method. ANSYS 12.1 package was used as a tool for finite element analysis. The pre-stressed beam was assumed as isotropic and simply supported. Calculation of stresses, bending moment and deflection in the beam was calculated manually and also by using ANSYS. On comparing, it is found that both the results are approximately equal. In this analysis rectangular cross section of beam was considered. Apart from it composite beams of varying cross section can also be analysed using FEM. They concluded as Flexural failure of the pre-stressed concrete beam was modelled well using a finite element package, and the load applied at failure was very close to hand calculated results. Deng Zhi-heng et al., Lenik et al., 2015 presented a study on process of testing and mathematical computation of model was described by the equations of function of the position and time for the nodes. The development of individual models and their groups and definitions of boundary conditions were carried out using computer program for finite element method. Basic equation of finite element method, Newton Raphson method and Jacobi methods were used for this analysis. From the result it was found that the result of the simulation models of plastic deformation processes carried out by the finite element method describes the behaviour of the system in space approximately and the results were always subjected to errors. Quality of the results depends on the boundary conditions, geometry of the study area, method of discretization, number and shape of finite elements and physical properties of the object 2005 The following conclusions could be made through the comparison of experiments and mechanism analysis of four joints of prestressed concrete beam and composite concrete column with core of concrete filled steel tube and one joint of ordinary prestressed frame structures. (1) Composite concrete column with core of concrete filled steel tube is a good reinforcement style that has prominent beneficial action on seismic behavior, and it can also improve the shearing capacity of joints. (2) Concrete could be effectively restricted by steel tube in core area. Development speed of the inclined cracks is more slowly than normal concrete structure joints after the inclined cracks occurred in joint area. (3) This kind of joints has good performance of ductility and energy dissipation capacity and the equivalent hysteretic damping factor is also larger than that of ordinary concrete frame structure joints.

III. MODELLING AND ANALYSIS

A. *Geometry*

- Size of the column = 300mm × 300mm
- Size of the beam = 300mm × 360mm

TABLE I. Material properties.

	Material	Element Type	Material Properties
1	steel	Young's Modulus	$2x10^5$ N/mm^2
		Poisson's ratio	0.3
		Yield strength	415 N/mm^2
2	Concrete	Young's Modulus	25000 N/mm^2
		Poisson's ratio	0.15
		Yield strength	3.5 N/mm^2
3	CFST tube	Young's Modulus	$2x10^5$ N/mm^2
		Poisson's ratio	0.3
		Yield strength	345 N/mm^2
4	Tendon	Tensile strength	1375 N/mm^2
		Young's Modulus	$2x10^5$ N/mm^2
		Poisson's ratio	0.3

B. *Loading Pattern*

Load is applied at the end of the beam is as shown in figure. The load pattern is in the form of tabular data with 5 cycles.

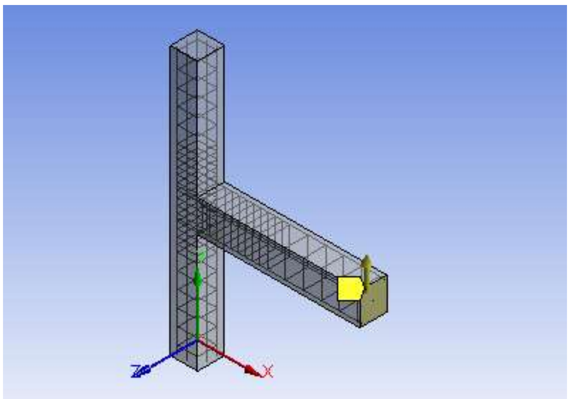

Fig. 1. Loading point on structure.

C. *Modelling of Structure*

The model for convensional beam column joint is shown in figure 2. The beam size is about 300 mm X 360 mm and column is about 300mm X 300 mm in size. And the structural design is done as per IS code provisions. Meshing of the beam column joint is done by advanced meshing and the mesh size is different for the structure and the CFST

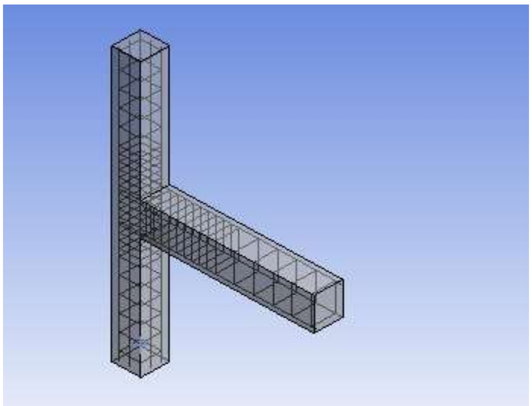

Fig. 2. Model of convensional beam column joint.

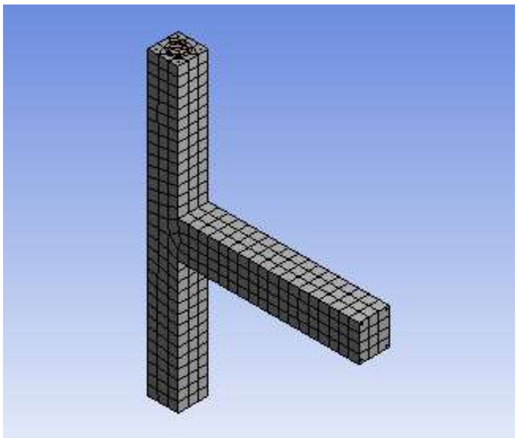

Fig. 3. Meshed view of a joint.

IV. RESULTS AND DISCUSSIONS

The data obtained from the analysis and compared in table II in terms of its percentage of variation.

A. *Total Deformation*

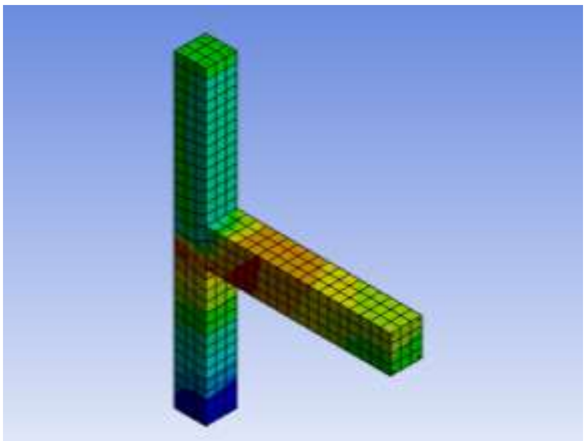

Fig. 3. Total deformation of a typical joint.

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B. Hysterisis Curve

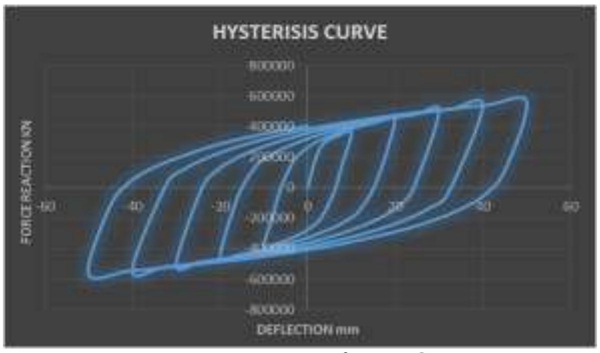

Fig. 4. Hysterisis curve of a typical joint.

C. Maximum Principal Stress

Maximum principal stress of a typical joint is shown in figure 5 with maximum value of 6.84 N/mm^2

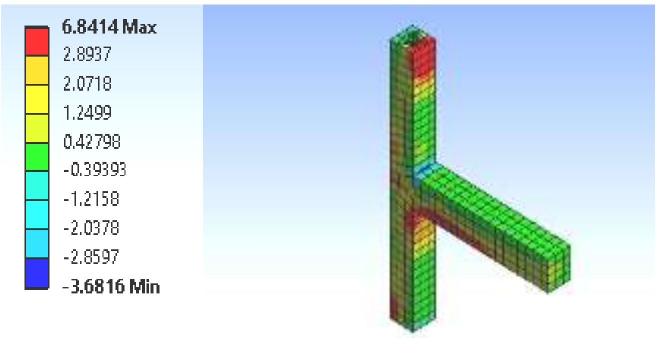

Fig. 5. Maximum principal stress.

TABLE II. Comparison of shear strength.

Types of Beam Column Joint Configuration		**Percentage of Variation of Shear Strength From 1st Model**
convensional beam column joint		0
beam column joint with concentric tendons	without CFST	14.3
	with CFST with hollow core	10.4
	with CFST	14.35
beam column joint with parabolic tendons	without CFST	11.3
	with CFST with hollow core	3.58
	with CFST	14.5
beam column joint with parallel tendons	without CFST	9.5
	with CFST with hollow core	11.7
	with CFST	2.4

TABLE III. Comparison of results.

Types of Beam Column Joint Configuration		**Maximum Principal Stress**	**Plastic Strain**
Convensional Beam Column Joint		**8.772**	**0.0061**
Beam Column Joint With Concentric Tendons	With out CFST	**10.061**	**0.0054**
	With CFST with hollow core	**8.496**	**0.199**
	With CFST	**5.025**	**0.001**
Beam Column Joint With parabolic Tendons	With out CFST	**7.68**	**0.0051**
	With CFST with hollow core	**6.8**	**0.008**
	With CFST	**7.86**	**0.1**
Beam Column Joint With Parallel Tendons	Without CFST	**11.665**	**0.0061**
	With CFST with hollow core	**6.83**	**0.0079**
	With CFST	**8.29**	**0.0052**

V. CONCLUSONS

Finite Element Analysis is conducted to develop models for the analysis of different types of beam column joints of prestressed structures. The structural response of the selected and designed prestressed beam-column connection of jointed systems under reverese cyclic load was compared . The following summarizes the conclusions :

- The shear strength of the beam column joint with parabolic tendon with concrete filled steel tube shows higher percentage variation from other joints.this type of joint shows 14.5 % higher strength than the convensional type beam column joint.
- Maximum principle stress of beam column joint with parrallel tendon shows higher value than others.
- Plastic strain is higher for beam column joint with concentric tendon with CFST with hollow core.
- Deformation is less for the beam column joint with parabolic tendon.

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