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Behavior of Reinforced Concrete Exterior Beam Column Joint Subjected to Seismic Loading

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***Abstract* - The present work aims to study the seismic performance of exterior beam column joint with the presence of inclined reinforcing bars in their core region. To model the complex behavior of reinforced concrete analytically in its non-linear zone is difficult. This has led engineers in the past to rely heavily on empirical formulas which were derived from numerous experiments for the design of reinforced concrete structures. FEM helps in the investigation of the behavior of the structure under different loading conditions, its load deflection behavior and the cracks pattern. In the present study, Analysis of nine RC beam column joint has been carried out with the intention to investigate the relative importance of several parameters such as load displacement graph, the crack patterns, propagation of the cracks and the crack width using ATENA software as well as experimentally.**

***Index Terms* - Exterior RC beam column joint, Inclined reinforcing bars, ATENA**

I. Introduction

Beam column joints are critical regions in multi-storey moment resisting reinforced concrete frames subject to inelastic response under severe seismic loading. Because seismic moments in columns and beams act in opposite directions across the joint, the beam–column joint is subjected to horizontal and vertical shear forces whose magnitude is often many times higher than those found in adjacent beams and columns. Since joints are also connecting elements of the load carrying columns, brittle failure such as shear or bond failure in the joints must be avoided. Therefore, in the design of the reinforced concrete beam–column joints against seismic load, it is desirable to limit joint strength degradation until the ductility capacity of the beam reaches the designed capacity. The functional requirement of a joint, which is the zone of intersection of beams and columns, is to enable the adjoining members to develop and sustain their ultimate capacity. The demand on this finite size element is always severe especially under seismic loading. The joints should have adequate strength and stiffness to resist the internal forces induced by the framing members.

The RC beam column joints are the most vulnerable part and subjected to damage firstly. Recent earthquakes worldwide have illustrated the vulnerability of existing RC beam-column joints of seismic loading. Poorly detailed joints performed as "weak links" in RC frames. The commonly seen deficiencies of damaged beam-column joints may be characterized as Insufficient shear strength, Inadequate anchorage or bonding and Insufficient flexural strength or ductility

II. DESCRIPTION OF THE STUDIED BEAM COLUMN JOINT

In this study, six half scaled beam column having dimension as shown in Table-1 below were tested under cyclic loading.

Table-1 Dimension of beam column joint

Types of joints	H (mm)	L (mm)	hc (mm)	bc (mm)	hb (mm)	bb (mm)
Column cross bars	900	850	150	100	100	150

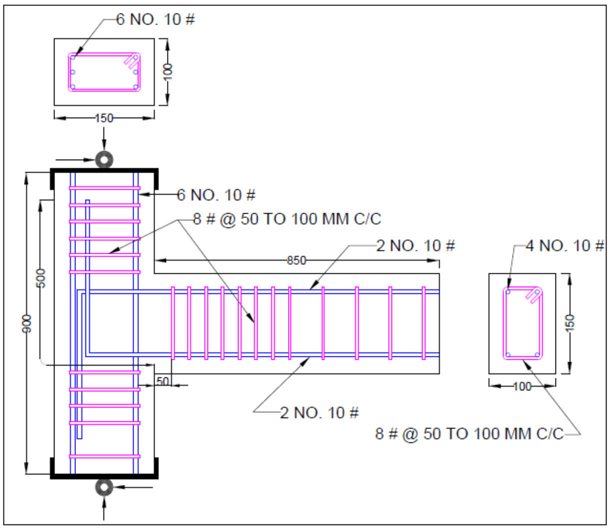


Figure 1 Seismic joint (IS13920)

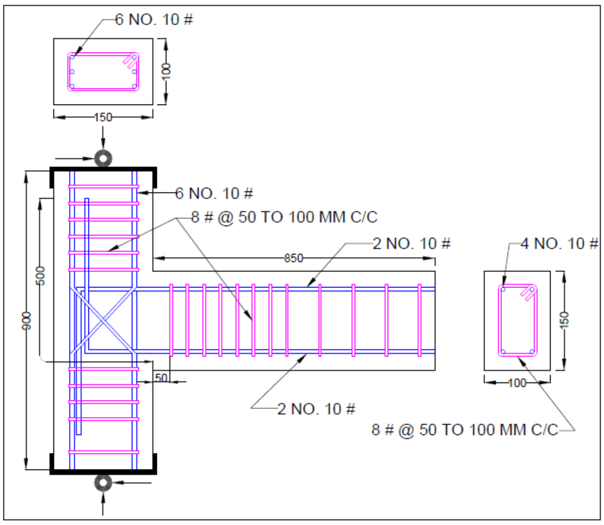


Figure 2 Inclined Reinforcing Bars

III. FINITE ELEMENT MODELING OF BEAM COLUMN JOINT

The finite element method (FEM) is the dominant discretization technique in structural mechanics. The concept of FEM modelling is the division of mathematical model into non-overlapping components of simple geometry. The response of each element is expressed in terms of a finite number of degrees of freedom characterized as the value of an unknown function. The finite element method is well suited for superimposition of material models for the constituent parts of a composite material. Advanced constitutive models implemented in the finite element system ATENA serve as rational tools to explain the behaviour of connection between steel and concrete. Nonlinear simulation using the models in ATENA can be efficiently used to support and extend experimental investigations and to predict behaviour of structures and structural details. Several constitutive models covering these effects are implemented in the computer code ATENA, which is a finite element package designed for computer simulation of concrete structures. The graphical user interface in ATENA provides an efficient and powerful environment for solving many anchoring problems. ATENA enables virtual testing of structures using computers, which is the present trend in the research and development world. Utilization of ATENA for simulation of connections between steel and concrete is good. In ATENA, concrete is represented by solid brick element, reinforcement by bar elements and FRP by shell elements. Material properties play an important role in modeling of a structure.

Material Properties of Concrete are as shown in Table 2 below:

Table 2 Material Properties of Concrete

Properties	**Values**
Elastic Modulus (Fresh concrete)	31720 MPa
Poisson Ratio	0.2
Tensile Strength	2.494 MPa
Compressive Strength	20 MPa
Specific Fracture Energy	4.421E-05 MN/m
Critical Compressive Displacement	5E-04 m
Plastic Strain at Compressive Strength	6.681E-04
Reduction of Compressive Strength	0.8
Fail Surface Eccentricity	0.52
Specific Material Weight	0.023 MN/mE+3
Coefficient of Thermal Expansion	1.200E-05 1/K
Fixed Crack Model Coefficient	1

Material Properties of Reinforcement Bars are as follow:

HYSD steel of grade Fe-415 of 10mm diameter is used as main steel while 8mm diameter bars is used as shear reinforcement. The properties of these bars are shown in Table below:

Table 3.2 Material Properties of Reinforcement

Table 3 Material Properties of Reinforcement bars

Properties	**Values**
Elastic modulus	200000 MPa
Yield Strength	415 MPa
Specific Material weight	0.0785 MN/mE+3
Coefficient of Thermal Expansion	1.2E-05 1/K

Material Properties of Steel Plate

The function of the steel plate in the ATENA is for support and for loading. Here, the property of steel plate is same as the reinforcement bar except its yield strength. The HYSD steel of grade Fe-415 was used for steel plate.

IV. ANALYTICAL ANALYSIS

The ATENA program, which is determined for nonlinear finite element analysis of structures, offers tools specially designed for computer simulation of concrete and reinforced concrete structural behavior. ATENA program system consists of a solution core and several user interfaces. The solution core offers capabilities for variety of structural analysis tasks.

ATENA 3D program is designed for 3D nonlinear analysis of solids with special tools for reinforced concrete structures. However, structures from other materials, such as soils, metals etc. can be treated as well. The program has three main functions:

A. Pre-processing
B. Run
C. Post-processing

A. Pre-processing: Input of geometrical objects (concrete, reinforcement, etc.), loading and boundary conditions, meshing and solution parameters.
B. Analysis: It makes possible a real time monitoring of results during calculations.
C. Post-processing: Access to a wide range of graphical and numerical results.

Procedure:
In pre-processing window following steps are performed:-
Step 1 : Geometry of FE model is created .It has been presented in Figure 3 and 4.
Step 2 : Material properties are assigned to the various elements of the RC beam-column joint specimen.
Step 3 : Structural element, various supports, loadings and monitoring points are defined. (Figure 3 and 4)
Step 4 : Finite element meshing parameters are given and meshing of the model is generated accordingly.
Step 5 : Various analysis steps are defined. The FE non-linear static analysis is done in Run window. The FE non-linear static analysis calculates the effects of cyclic loading conditions on a structure. Static analysis is used to determine the displacements, stresses, strains, and forces in structures or components by displacements.
Step 6 : When the FE non linear analysis is completed the, the results are shown in third part of the ATENA i.e. Post processing. The stress- strain values at every step, crack pattern and cracks propagation at every step shown help in to analyze the behaviour of the elements at every step of load deflection.

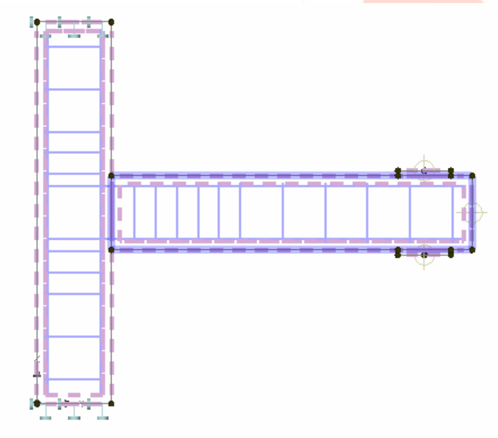


Figure 3 Geometry of FE model

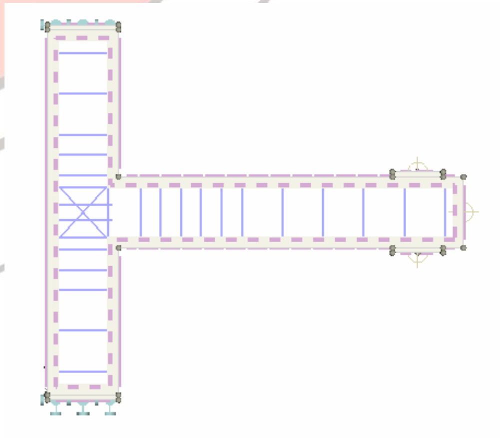
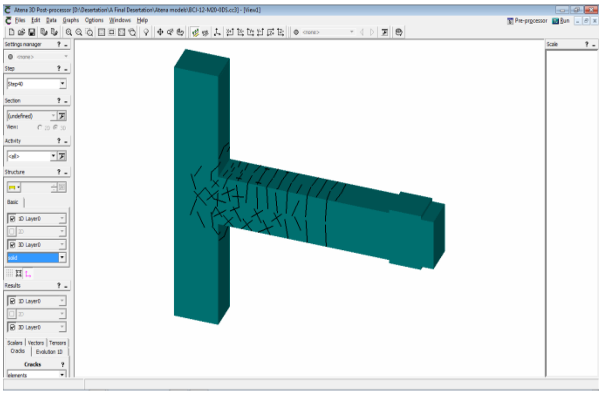
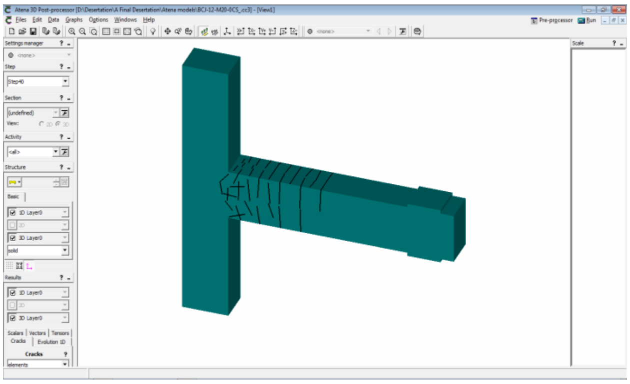


Figure 4 Geometry of FE model

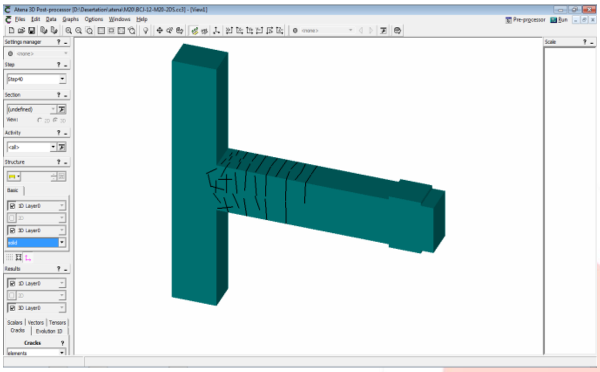
V. RESULTS AND DISCUSSION



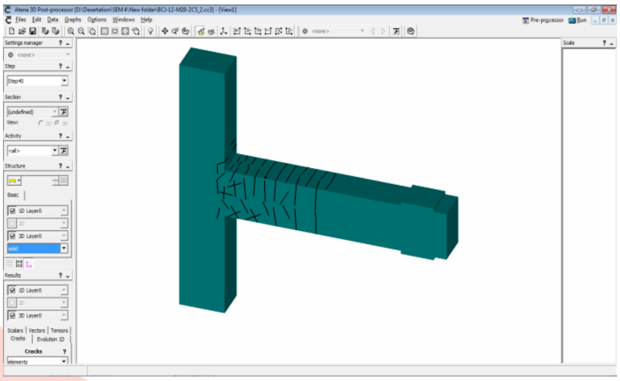
Ductile specimen with zero lateral ties



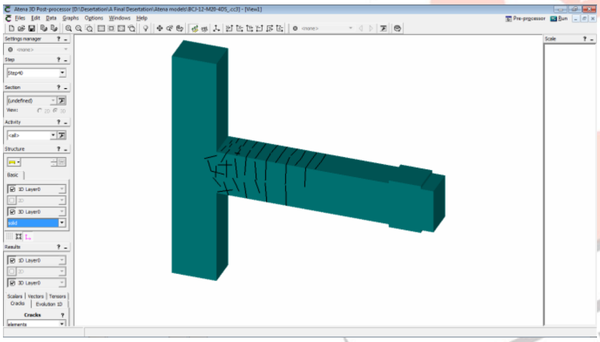
Specimen with inclined cross bars and zero lateral ties



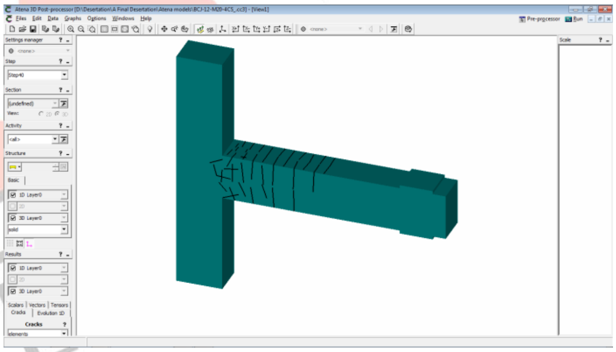
Ductile specimen with two lateral ties



Specimen with inclined cross bars and two lateral ties



Ductile specimen with four lateral ties



Specimen with inclined cross bars and four lateral ties

VI. CONCLUSION

- Exterior beam-column joints with additional single crossed inclined column reinforcing bars showed high strength, and appreciable deterioration after reaching their maximum capacity.
- Single crossed inclined column reinforcing bars with zero, two and four lateral ties failed at the beam-column interface satisfying the strong column weak beam theory.
- Exterior beam-column joints as per ductile detailing showed less strength as compared to inclined cross bars specimen.
- Ductile specimen with zero lateral ties showed the worst behavior in terms of load carrying capacity and also it showed joint failure which is unacceptable.

VII. REFERENCES

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