International Journal For Technological Research In Engineering
Volume 7, Issue 12, August-2020 *ISSN (Online): 2347 - 4718*

ANALYTICAL STUDY USING ANSYS ON THE BEHAVIOR OF EXTERIOR BEAM-COLUMN JOINTS SUBJECTED TO STATIC LOADING AND SEISMIC LOADING

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ABSTRACT: The research focuses on the behaviour studies of exterior beam- column joints subjected to static loading and seismic loading, using the reinforcement conditions as (i) normal reinforcement steel as per IS 456-2000, (ii) with steel fibers, (iii) using diagonal bars at the joint, (iv) diagonal bars and fibers at varying length and heights in beam and column directions. Studies were carried out analytically using ANSYS, measuring parameters like i.e. maximum principle stress, maximum shear stress, displacement, rotations, displacement ductility, energy dissipation, yield load and ultimate load. Static cyclic load test was done on 1:3 scaled down models to understand the behaviour of the joints. Force controlled tests were done to measure the ductility of the specimens. Based on the hysteretic curve the energy dissipation capacity for various specimens was estimated. The comparison of ultimate load between the analytical load and experimental investigation had marginal variations. The maximum shear stress obtained in static loading is 7.51 MPa whereas the maximum shear stress under dynamic loading is 10.72 MPa with a percentage increase of 42.74%. The maximum bending stress obtained in static loading is 17.34 MPa whereas the maximum bending stress under dynamic loading is 18.27 MP with a percentage increase of 5.36%. The analysis and experiment results showed that using additional diagonal cross bracing bars and steel fibre reinforcement is an effective method to reduce the lateral reinforcement in the beam plastic hinge region. An effective method to increase ductility of RCC external beam column joint is by adding cross diagonal bars and steel fibres at the joint and by extending in beam and column directions.

I. INTRODUCTION

Analysing post-earthquake pictures does vividly teach about what designs were faulty and why. Unfortunately, that cannot be said from the structures that were not damaged because from the outside little can be seen. Only the study of the drawings and calculations can determine why, a certain structure did not fail, and while neighbouring structure were damaged or totally collapsed. In particular those constructions that are at the point of total failure are interesting because they present themselves as a freeze frame during the process of collapsing. Performance-based seismic analysis are emphasized in recent years by earthquake engineers as a need. Determination of ultimate inelastic response of the structure is an essential element in many seismic evaluations. Inelastic deformation or damage in structures require reasonable estimates using performance-based methods which are better quantities to assess damage than stress or forces. The performance based analysis is under the lateral forces of an earthquake of a certain level of seismic hazard based on quantifying the deformation of the members. Present codes are based on elastic analysis which has no measure of the deformation capability of members. Based on limit state method of design the performance based analysis gives the analyst more choice of 'performance' as compared to the limit states of collapse and serviceability.

II. BEAM-COLUMN JOINT

It is well recognized and accepted that in earth quake resistant design, all structural members, their connections and supports should be designed with large ductility and stable hysteretic behaviour so that the entire structure will also be ductile and display stable hysteretic behaviour. Beam column joints are critical regions in multi storey moment resisting reinforced concrete frames subjected to inelastic response under severe seismic loading. 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 respectively. 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. It has been identified that, the deficiencies of joints are mainly caused by inadequate transverse reinforcement and insufficient anchorage capacity in the joint (Liu, 2006). Even if other structural members confirm to the design requirements, the unsafe design and detailing within the joint region jeopardizes the entire structure.

II. OBJECTIVES OF THE PROPOSED RESEARCH PROJECT

- To study the implementation of diagonal bars in the beam column junction to reduce the congestion of reinforcement in the joints
- To increase the ductility of the beam column joints by providing steel fibers in the joints
- To experimentally validate the analytical results using cyclic load tests

III. METHODOLOGY

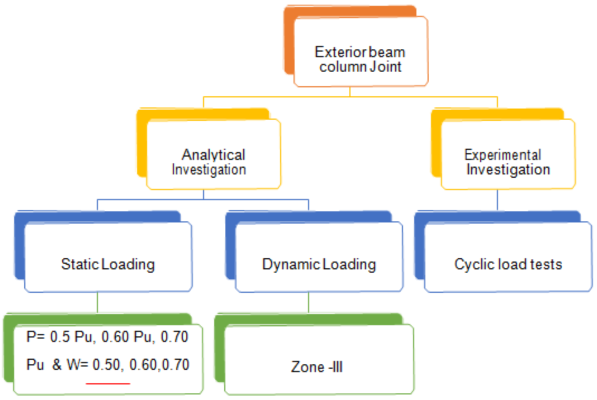

Figure Flow chart for research methodology

IV. EXPERIMENTALINVESTIGATION

This chapter gives brief description on the experimental investigation carried out to study the behaviour of beam column joint subjected to cyclic loading. The number of beam-column joint specimens tested during this investigation is 5, out of which 1 specimen designed and detailed as per code IS 456:2000 and 2 specimens with additional diagonal bars at the joint and extending in beam and column directions and 2 specimens with steel fibres at the joint and extending in beam column directions. The strength of concrete used for casting the specimens were find out by taking concrete cubes with the same concrete used for the specimen castings. Six cubes were taken and tested the 28 days compressive strength. The compressive strength of concrete used is 27 N/mm2. Similarly the properties of steel reinforcement used for the specimens were found out by testing the sample reinforcements steel in laboratory. The tensile strength obtained for the reinforcement steel used for casting the specimens is 435 N/mm2. The ANSYS 16 analysis is validated by using the actual strength of concrete and reinforcement steel used for the specimens casting.

V. SPECIMEN OF THE EXPERIMENTAL

Specimen were test as T Shape to depict an exterior beam column joint. Column size of the specimens are 1000 mm x 175 mm x 150 mm. Beam size are 600 mm x 175 mm x 150 mm. The material properties of steel fibre used are DRAMIX ® 3D with tensile strength 1225 N/mm2, Young's modulus 210000 N/mm2, length 60 mm, aspect ratio 80 and diameter 0.75 mm. The grade of concrete is M 20 and the grade of steel is Fe 415 for main reinforcement & transverse reinforcement. Fe 415 grade bars of 10 mm ø have been used as the tension reinforcement and 8mm ø have been used as compression reinforcement in beam with 6 mm dia. In beam, 6 mm ø stirrups had been adopted at a spacing of 100mm centre to centre. Four numbers of 12 mm diameter tor steel has been provided as longitudinal reinforcement in column and 6 mm diameter bar was adopted for the lateral ties at 150 mm centre to centre.

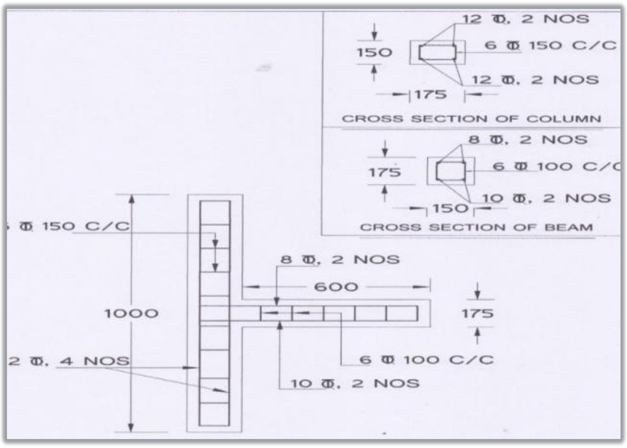

Figure 5.4 RCC beam column joint reinforcement details

Table 5.1 Details of number of specimens tested.

Sl.No	Description of specimen	Number of specimens tested	Type of testing
A	Normal (as per IS 456- 2000)	1	Cyclic load
B	With additional diagonal bars at the joint	1	Cyclic load
C	With additional diagonal bars at the joint and extending in beam (.3B) & column(.3H)	1	Cyclic load
D	With additional fibre at the joint	1	Cyclic load
E	With additional fibre at the joint and extending in beam (.3B) & column (.3H)	1	Cyclic load

DUCTILITY OF SPECIMENS

The displacement ductility of all the specimens tested in laboratory is presented in table 5.2. It can be seen that the displacement ductility is more for the beam column joint with additional cross diagonal bars and additional steel fibres. The percentage increase is 70% and 50%.The ductility increment is more for the beam column joint with additional diagonal cross bars than with additional fibres by 20%.It can be seen that the displacement ductility factor for beam column joint with additional cross bracing bars is 48.57% more than that of normal beam column joints. Also, it can be seen that the results are better for the beam column joints with non-conventional diagonal bars extending on beam and column directions by 0.3H and 0.3B.

Table Displacement ductility of specimen tested in laboratory

Displacement (mm)							
Specimen	yield		Ultim e at		Displaceme nt ductility		Average displaceme nt ductility
	Down ward direction	Upward direction	Down ward direction	Upward direction di	Down ward rection	Upward direction	
A	4.70	4.60	16.50	16.00	3.50	3.50	3.50
B	4.17	3.70	21.50	19.50	5.15	5.25	5.20
C	3.40	4.40	15.00	33.00	4.40	7.50	5.95
D	3.70	3.75	17.29	22.45	4.30	5.90	5.10
E	4.10	4.13	18.67	24.78	4.50	6.00	5.25

Table 5.3 Yield load and ultimate load of specimen tested in laboratory

Specimen	Downward direction	Upward direction	Average (Pye)	Downward direction	Upward direction	Average (Pue)
A	15.35	15.50	15.45	18.25	18.75	18.50
B	17.80	18.10	18.45	21.50	22.50	22.00
C	22.50	23.75	23.12	25.25	26.75	26.00
D	18.38	18.75	18.48	20.50	21.50	21.00
E	19.00	19.25	19.12	22.00	24.00	23.00

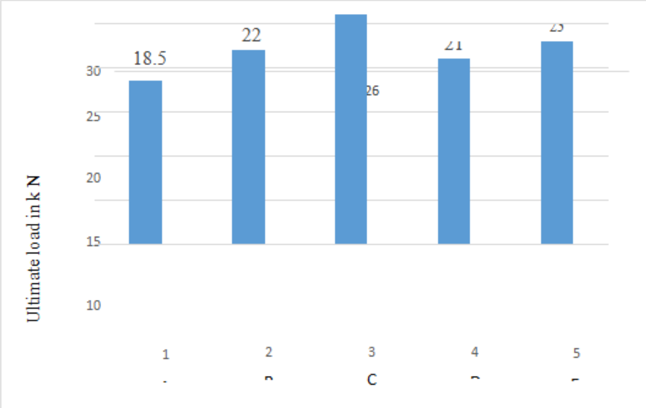

Figure Ultimate load of specimens

Figure shows the average displacement ductility of specimens. It can be seen that the displacement ductility is more for the beam column joint with additional cross diagonal bars and additional steel fibres. The percentage increase is 70% and 50%.The ductility increment is more for the beam column joint with additional diagonal cross bars than with additional fibres by 20%. The rotation of the beam column joint with additional cross diagonal bars and steel fibres are more and hence the displacement at ultimate load is more. The displacement ductility increases with the joints with non-conventional bars and fibres. It can be seen during experiment that the non-conventional joint cracks are developed beyond the joint along the beam and the ultimate load carrying capacity of the joint increases due to formation of plastic hinge in the beam.

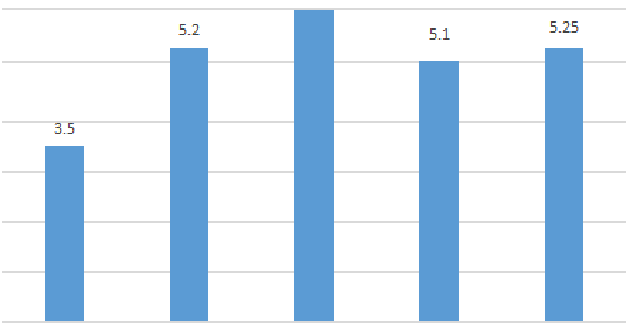

Figure Average displacement ductility of specimens

SUMMARY

The strength of beam-column joint plays a very important role in the strength of the structure under different loading conditions. Beam column joints can be critical regions in reinforced concrete frames designed for inelastic response to severe seismic attack. For structural safety, especially for reinforced concrete beam–column joints, ductility of the joints has to be increased. The objective is to analytically illustrate and experimentally prove the various techniques for improving the joint ductility of exterior beam-column joints.

Beam column joint analysis

The following models were considered for the analytical study in static loading in linear range, dynamic loading in linear range and Non-linear analysis (static and dynamic). An ANSYS model has been developed and analysed to study the behavior of exterior beam-column joint specimens subjected to static load and dynamic load. Analysis has also been carried out to determine load carrying capacity and energy absorption capacity of beam-column joint specimens. In the present study, analytical study was performed using ANSYS for the following models

- Conventional model designed as per IS 456:2000
- with additional diagonal bars at the joints and extending in the beam directions in 0.1B, 0.2B and 0.3B and along the column directions in 0.1H, 0.2H and 0.3H
- with additional steel fibers at the joint and extending in column direction in 0.1H, 0.2H and in beam in 0.3 H and 0.1B, 0.2B and 0.3B.

The ductility and energy dissipation, the seismic strength and performance of reinforced concrete exterior beam–column joints under static and cyclic loading applied to the beam end were studied. The exterior joints were studied with different parameters like i.e. maximum principal stress, minimum principal stress, displacement, rotations, displacement ductility, energy dissipation capacity, stiffness variation of beam column joint using ANSYS modelling. Specimens were cast at laboratory and tested. The exterior beam-column joints were studied both analytically and experimentally.

Experimental investigation of beam column joint

Experimental investigation was carried out to study the behaviour of beam column joint subjected to cyclic loading. The number of beam-column joint specimens tested during this investigation is 5, out of which 1 specimen designed and detailed as per code IS 456:2000, 2 specimens with additional diagonal bars at the joint and extending in beam and column directions and 2 specimens with steel fibres at the joint and extending in beam column directions. Experimental investigation has been carried out by casting five samples and tested in laboratory specimen A-Normal (as per IS 456: 2000), B-With additional diagonal bars at the joint, C-With additional diagonal bars at the joint and extending in beam (0.3B) & column (0.3H), D-With additional fibre at the joint, E-With additional fibre at the joint and extending in beam (0.3B) & column (0.3H). Specimen size (T Shape) column size- 1000 mm x 175 mm x 150 mm and beam size- 600 mm x 175 mm x 150 mm.

VI. CONCLUSIONS AND FINDINGS

Analysis and experimental investigations

- The RCC exterior beam-column joints were studied analytically and experimentally. For enhancing beam column joint ductility, parameters like i.e. maximum principal stress, maximum shear stress, displacement, rotations, displacement ductility, energy dissipation, yield load and ultimate load were considered.
- It is concluded from the ANSYS analysis and experiments that the results are closely matching and the maximum variation in ultimate load is 12.85% (for specimen A) and minimum variation is 1.52% (for specimen B).
- From the analysis and experiment it is concluded that an effective method to increase ductility of RCC external beam column joint is addition of cross diagonal bars and steel fibres at the joint and extending in beam and column directions.
- From the analysis and experiment it is concluded that the yield load carrying capacity and ultimate load carrying capacities of the specimens are increasing by using the non-conventional cross diagonal bars and steel fibre at the beam column joint.
- From the analysis and experiment it is concluded from the analysis and experiment results that using additional diagonal cross bracing bars and steel fibre reinforcement is an effective method to reduce the lateral reinforcement in the beam plastic hinge region.
- From the analysis and experiment it is concluded the diagonal bar in the beam column junction reduces the congestion of reinforcement in the joints. Strong column weak beam will become effective by this method as can be seen that the cracks are not developed at the joint and is developed in the beam with formation of plastic hinges. The failure is local and not global. The cracks width is also less and hence repair work is easy in the beam region being local failure.

SCOPE FOR FUTURE STUDIES

- Further study of RCC exterior beam column joints can be carried out for increasing shear strength and shear ductility within the joint with different materials.
- Further study can be carried out using advances in the field of material science to improve the joint ductility of members or critical sections and schemes for improving the joint ductility.

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