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COMPARISON BETWEEN ANALYTICAL AND EXPERIMENTAL BEHAVIOR OF INTERIOR RC BEAM COLUMN JOINT USING STEEL FIBERS UNDER CYCLIC LOADING

[1] GNANAMBHAVARI SAI PRASAD *, [2] Ms. C.PAVITHRA

[1] P.G Student [2]Assistant Professor Department of Civil Engineering, SRM University,

Kattankulathur, Chennai, Tamilnadu-603203 India.

ABSTRACT

Earthquake produces sudden shaking of earth surface which causes damages to structures. The structures which are constructed in earth quake zone should be able to withstand the forces from earthquake. The most crucial zone which effects the structural behavior during earthquake is beam column joint. So, the beam column should be strong enough to resist the loads. This paper presents behavior of RC beam column joints using steel fibers under cyclic loading both experimental and analytical. A total of four RC beam column joints are casted and cured for 28 days with and without steel fibers in RC beam column joint and wide beam-narrow column joint. Cyclic loading is applied on R.C sections at an incremental load of 5KN in forward and reverse direction till the sections are failed from the results, the ultimate load of the RC beam column joint with steel fibers has increased to 25% of conventional section. These results are compared analytically in ANSYS which shows that the behavior of RC beam column sections is found similar to that of experimental results.

Key words: Steel fibers, Wide beam-narrow column, LVDT, Cyclic loading

INTRODUCTION

In RC buildings the portion at which columns and beams intersects are called beam column joints. Since their constituent materials have limited strengths, the joints have limited load carrying capacity. Beam column joint is an important component of a reinforced concrete structure and should be designed properly to resists the moments during earth quakes. There are several international codes which gives high importance to provide adequate anchorage to longitudinal bars and confinement of concrete to resist shear.

Under earthquake shaking, the beam column joints are subjected to moments in same direction either in clockwise or counterclockwise direction. Under these moments, the top bars in the beam column joint are pulled in one direction and the bottom ones in the opposite direction. These forces can be resisted by improving the bond stress between concrete and steel in the beam column intersection area. If the beam is wide enough, there will be sufficient bonding between concrete and steel bars. Therefore it can carry more loads. But if the beam is not wide enough the bonding between concrete and steel bars will be low. In such circumstances, during earth quakes the steel bars inside the RC beam column joint slips near the joint region, and beams losses their strength. Further, under the action of the above pull push forces at top and bottom ends, joints undergo geometric distortion; One diagonal length of the joint elongates and the other compresses. If the column cross-sectional size is insufficient, the concrete in the joint develops diagonal cracks. Repairing damaged joints is difficult; therefore preventive measures should be taken to resist these damages. Hence, an attempt has been made to study the behavior of RC beam-column and wide beam-narrow column joints with and without steel fibers under cyclic loading.

NEED FOR THE RESEARCH

The experimental investigation carried out for evaluating the seismic response of RC wide beam-narrow column joints under cyclic load and for exploring the potential of improving the seismic performance of the same joints without introducing significant changes in the design and construction practices. This research concentrates on the interior joints, in which four full-scale beam-column sub-assemblages are tested under cyclic loading. With a slight improvement of the reinforcement detailing by delaying the joint shear failure, crack pattern and energy dissipation capacities are compared analytically using ANSYS software

MATERIALS

The following materials are used in casting the beam column joints

Cement

Portland-Pozzolana cement of grade 53 confirming to IS 1489 (Part 1): 1991 was used for casting all the specimens. Specific gravity and fineness modulus of cement is 3.15 and 7.5 respectively.

Fine aggregate

Fine aggregate which is available locally available near SRM university is used. From the grain size analysis fine aggregate passes through 4.75mm sieve. Specific gravity and fineness modulus is 2.64 and 2.79 respectively.

Coarse aggregate

Coarse aggregate is collected from quarry near Chennai. The aggregates passing through 12.5 mm sieve as given in IS 383 – 1970 are used for casting the specimens. Specific gravity and fineness modulus is 2.77 and 5.90 respectively.

Steel fibers

Crimped type Steel fibers with an aspect ratio of 80 were used for beam column joints.

EXPERIMENTAL INVESTIGATION

Mix proportion

Mix design for M30 grade of concrete is adopted from IS 10262:2009. The quantity of the material is given in the below table

Table: Mix proportion for beam column joint

Type of beam column joint	Cement (kg)	CA (kg)	FA (kg)	Water (lit)	Steel fibres (kg)
Conventional	15.13	42.58	28.5	6.8	-----
Steel fibre	14.97	42.15	28.21	6.73	0.9
Wide beam narrow column joint	15.13	42.58	28.5	6.8	-----
WB-NC joint with steel fibre reinforcement	14.97	42.15	28.21	6.73	0.9

Reinforcement details

Three main bars of 10 mm diameter are provided in beam and tied with stirrups of 6 mm diameter at 30 mm c/c for a distance of 2D i.e, 300 mm and at 60 mm c/c for remaining length of the beam. 8 bars of 8 mm diameter are provided in the column and tied with stirrups of 6 mm diameter bars at 30 mm c/c for a distance of 150 mm from face of column and at 60 mm for remaining length of beam as shown in figure 1.

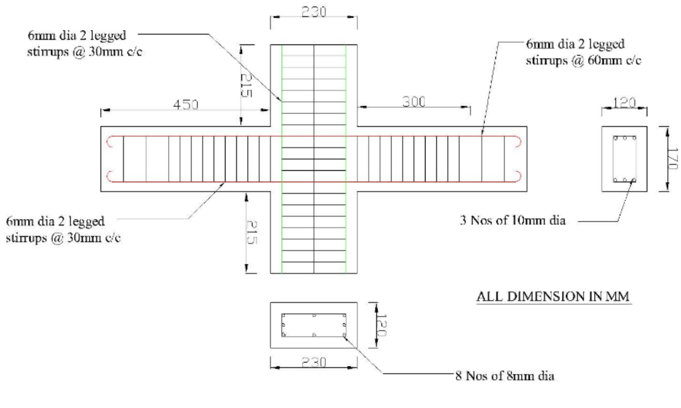

Figure 1: Reinforcement details of Beam-Column joint

Casting and curing:

The mould is arranged properly and placed over a smooth surface. The sides and bottom of the mould were oiled well to facilitate easy removal of the specimen. The reinforcement cages were placed in the moulds with a clear cover of 25 mm from end of cage. Concrete mix designed for M30 (1:1.5:2.5) and water cement ratio is 0.45. Cement mortar block pieces were used as cover blocks. The materials for concrete such as cement, sand, aggregate and water were weighed accurately and mixed uniformly. The concrete was placed into the mould immediately after mixing and well compacted. The test specimens were remolded at the end of 24 hours of casting and are cured in water for 28 days. After 28 days of curing the specimen was dried in air and white washed.

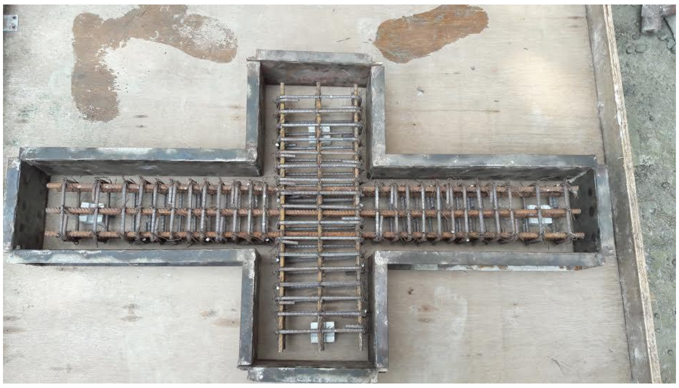

Figure 2: Reinforcement of beam column joint

Test setup and instrumentation:

The beam column joint specimens are tested under cyclic loading. The load was applied in forward and reverse direction through a hydraulic jack. The loads are applied at equal increments of 5 KN in forward direction till the failure of specimen are applied in forward direction and deflections are measured. Similarly the loads are applied in reverse direction and deflections are measured. Test setup for Beam column joints and wide beam narrow column joints are shown in figure 3 and 4.

Figure 3: Test setup of Beam-Column joint

Figure 4: Test setup of wide Beam-Narrow Column joint

EXPERIMENTAL RESULTS

Tests are carried out on conventional and steel fiber reinforced beam column joints and the results are shown in table 2.

Table 2: Test results of beam column joints

Sno	Type of Beam column joint	Cracking load in kN	Ultimate load in kN
1	Conventional beam column joint	15	45
2	Steel fiber reinforced beam column joint	19	60
3	Wide beam-narrow column joint	14	48.5
4	Steel fiber wide beam-narrow column joint	17	63

FAILURE PATTERN

All the beam column joints exhibit a reasonably ductile performance and the failure results from the yielding of high performance concrete followed by the crushing of concrete. At about 10kN of load, the initial crack is appeared in the specimen as shown in figure 5. With further increase in the load, regularly spaced vertical cracks were observed.

Figure 5: Failure pattern of Beam-Column joint

Results

Load deflection curve of beam column joint

In conventional concrete beam column joint, the specimen undergo suitable number of cycles and deflection is to be observed and when we compare the deflection of the steel fiber reinforced beam column joint, the deflection will be increased with the increase in the number of cyclic loads. From the graph it is clear that the maximum deflection in conventional beam joint is higher than that of the steel fiber reinforced beam column joint.

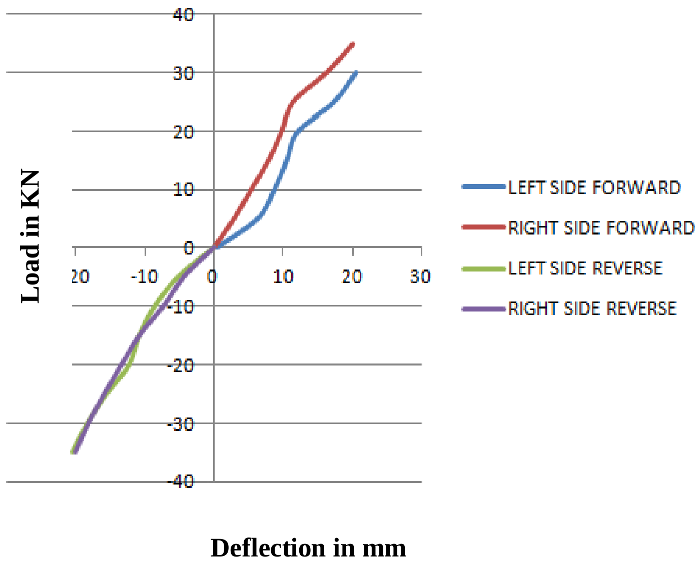

Figure 6: load deflection curve of conventional beam column joint

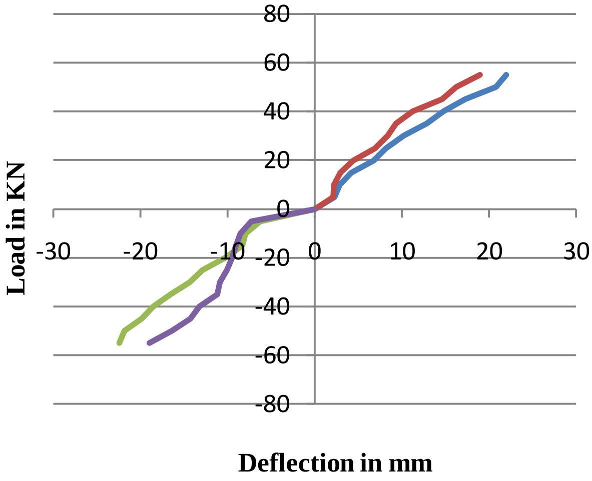

Figure 7: Steel fiber beam column joint

Load deflection curve of wide beam-narrow column joint

Figure 8 and 9 represents the load deflection curves of wide beam narrow column joints with and without steel fibers .from the graph

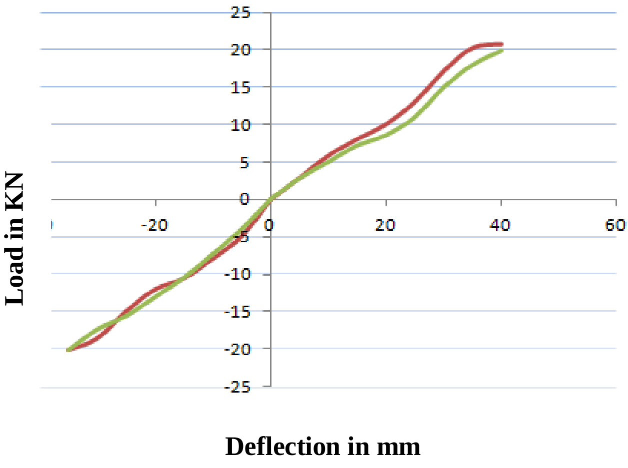

Figure 8: wide beam-narrow column joint

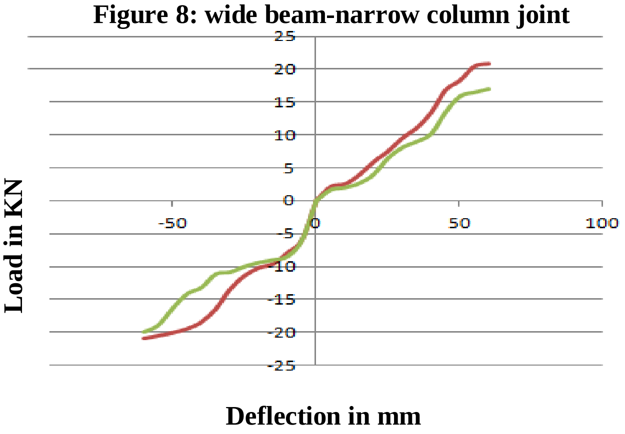

Figure 9: steel fiber wide beam narrow column joint

Stiffness of beam column joint

The stiffness of both the beam column joints with and without steel fibers are shown in the fig 10 and 11. In the conventional beam column joint about 73% of the stiffness is observed, where as in steel reinforced interior beam column joint about 84% is observed.

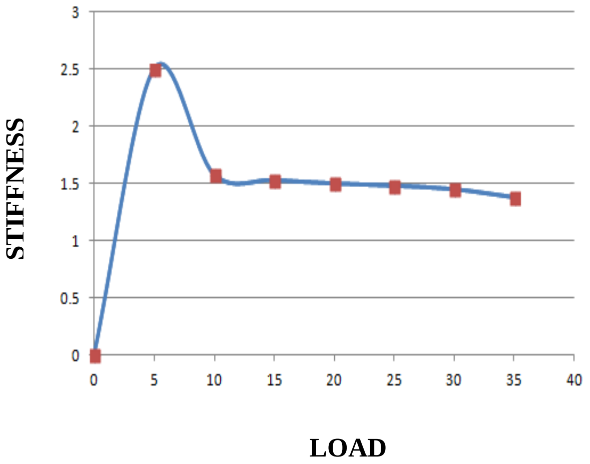

Figure 10: Conventional beam column joint

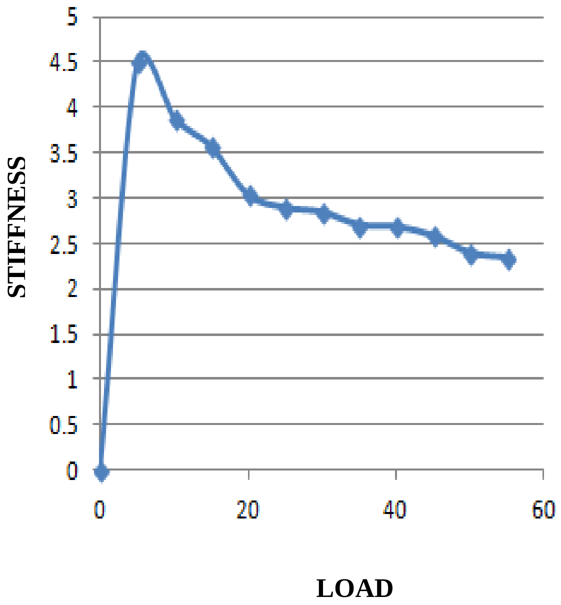

Figure11: Steel fiber beam column joint

Stiffness of wide beam narrow column joint

The stiffness of both the beam column joints with and without steel fibers are shown in the fig 10 and 11. In the conventional beam column joint about 77% of the stiffness is observed, where as in steel reinforced interior beam column joint about 91% is observed.

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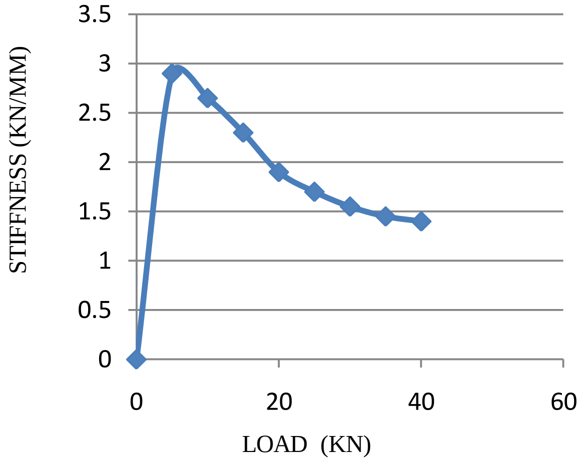

Figure12: Variation of stiffness with load in wide beam narrow column joint

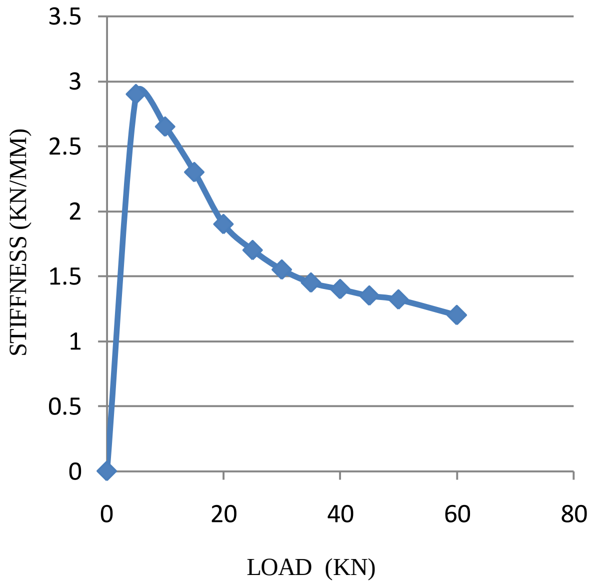

Figure 13: Variation of stiffness with load in reinforced wide beam narrow column joint

ANALYTICAL PROGRAM

After experimental program the beam column joint with steel fibers reinforcement is designed in ANSYS and is tested by applying cyclic loading in forward and reverse direction. Then the results are compared with experimental results. The following figure 12 shows the modeling of beam column joints by using software "ANSYS"

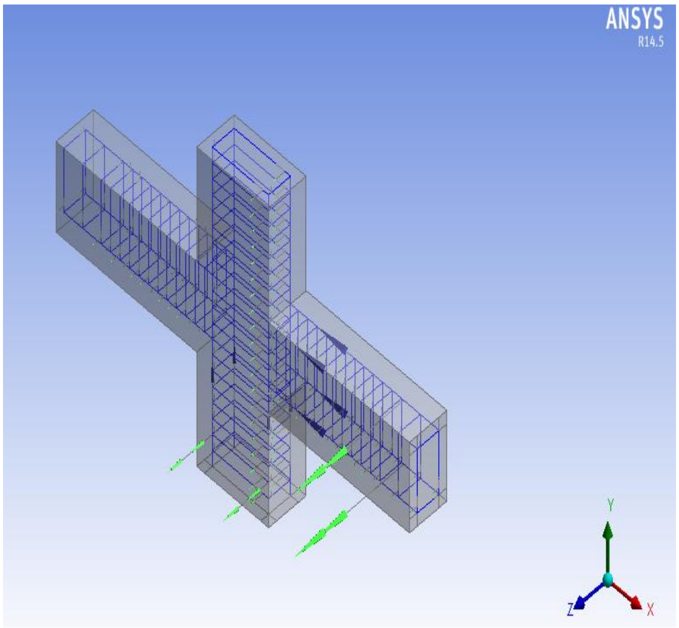

Figure 14: modelling of beam column joint

Results
DEFORMATION

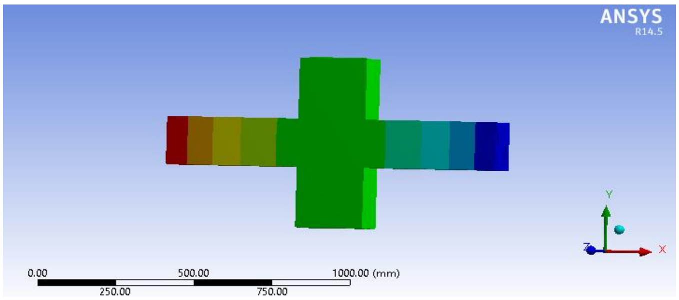

Figure 15: deformation of beam column joint

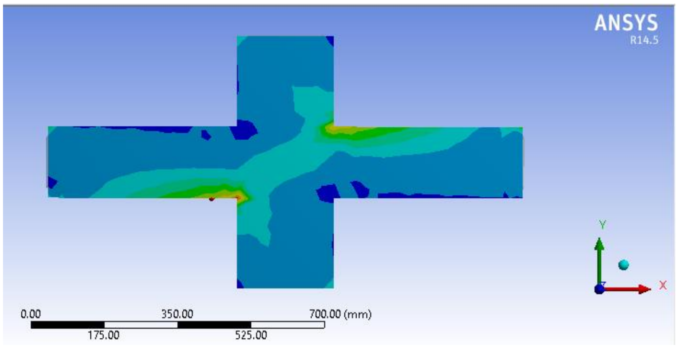

Figure 16 maximum principal stress (steel fibers)

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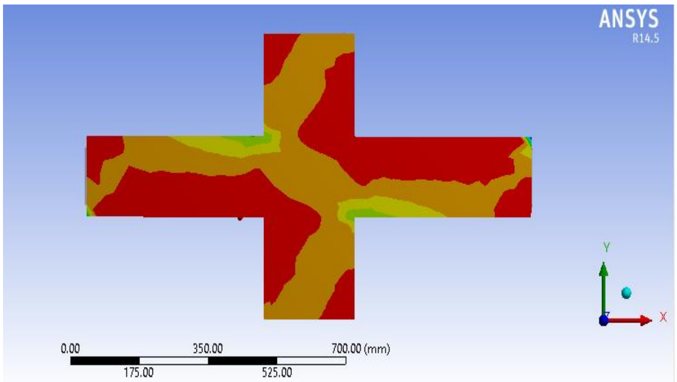

Figure 17: minimum principal stress

Failure pattern

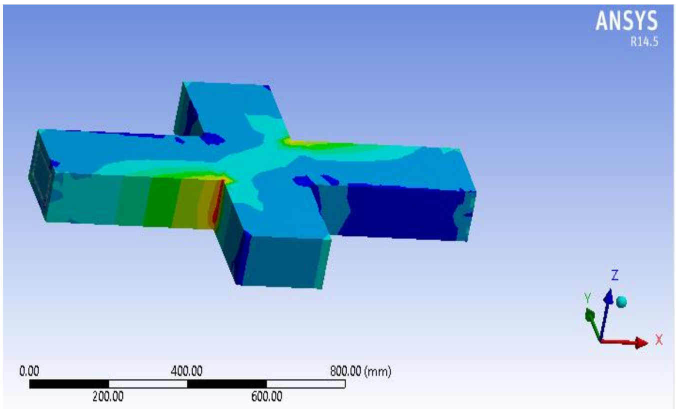

Figure: Failure pattern of beam column joint

Comparison of experiment study and FEM analysis

Experimental results are compared with FEM model analysis in ANSYS, the behavior of the interior beam column joint are similar. Maximum stresses are occurred at the beam column junction. The crack patterns are formed and clearly visible in the model

Conclusion:

The structural behavior of interior RCC beam column joint has been studied both experimentally and analytically by using ANSYS. From test results, important parameter has been worked out such as stiffness degradation, deflection in order to access the seismic behavior of the beam column joint when earthquake comes. Experimental investigation has been carried out and test results shows that the structural behavior of interior wide beam–narrow column joint model has improved when compare to that of beam column joint in both conventional and steel fiber reinforced sections. The results obtained for beam column joint both experimentally and analytically are similar.

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