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A Numerical Study on Steel Fibre Reinforced Concrete Beam Column Joint

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Abstract—*The main aim of the study is to compare the behavior of the Steel Fiber Reinforced Concrete with that of the Normal concrete. Software modeling of beam column joints using ANSYS and the deflection study of the model will also be done. The present research work aims to investigate numerically & experimentally the behavior of steel fiber reinforced concrete beam column joints under seismic action. Exterior joint were examined and 3D nonlinear finite element analysis will be carried out using ANSYS software. This is particularly useful for joints designed to withstand seismic loading as code requirements lead to a high amount of shear links provided to protect critical regions. Potential enhancement to ductility, a key requirement in seismic design, will be investigated as well as potential improvements to energy absorption and confinement. The work also will be examined key structural issues such as strength, storey drift, plastic hinges formation and cracking patterns.*

Keywords: *Beam column joint, concrete, cyclic loading, Joint designed as per IS 13920:1993, Steel fiber, Strong-column weak beam.*

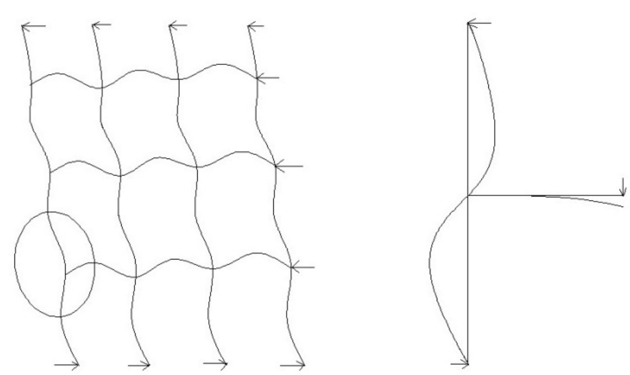
1. INTRODUCTION

In RC buildings, portions of columns that are common to beams at their intersections are called beam-column joints. Since their constituent materials have limited strength, the joints have limited force carrying capacity. Force comes from both horizontal & vertical direction during earthquakes, results joints are severely damaged. That's why we design beam-column joints as per IS 13920:1993. Under earthquake shaking, the beams adjoining a joint are subjected to moments in the same (clockwise or counter-clockwise) 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 are balanced by bond stress developed between concrete and steel in the joint region. If the column is not wide enough or if the strength of concrete in the joint is low, there is insufficient grip of concrete on the steel bars. In such circumstances, the bar slips inside the joint region, and beams loose their capacity to carry load.

Fiber reinforced concrete (FRC) is relatively a new construction material developed through extensive research and development work during the last two decades. It has already found a wide range of practical applications and proved to be a reliable construction material having superior performance characteristics compared to conventional concrete. In this study the scraps from the lathe shops are used as the steel fibers.Faber reinforced concrete is relatively a new construction material which is used during the last two decades. It has already found a wide range of practical applications and proved to be a reliable construction material compared to conventional concrete. By adding steel fibers to reinforced concrete the joint is toughened which enables the structure to be more durable. To increase the strength of joint we follow IS-13920-1993. Nevertheless, this can result in reinforcement congestion which causes difficulties during concreting (i.e. incomplete_compaction of concrete) and increases construction costs.

2. SELECTION OF SPECIMEN

The deflected shape of a RC frame is subjected to lateral loading is shown in Figure.1 (a) where the points of contraflexure lie at the mid-points of beams and columns. Further, the free body diagram of an external BC sub-structure assembly is shown in Figure.1 (b). We have one half of a column at top and bottom as well as one half of a beam.



(a) **(b)**

Fig. 1: (a) Deflected shape of a RC frame under lateral loading (b) Isolated exterior Beam-Column joint.

3. DETAILS OF THE SPECIMEN

Two one third scaled beam-column joint specimens have been considered, namely RCBC (reinforced concrete Beam-Column as control specimen), SFBC (steel fiber Beam-Column). All specimens have been designed of ductile detailing as per IS: 13920:1993. The cross sectional dimension and design were adopted same, only difference was materials provided in the BC joint. The cross section of the column was taken as 100mmX120mm and the beam took as 100mmX100mm for all specimens. Four number of high strength deformed bar (Yield strength 500MPa) of 8mm diameter was used as reinforcement in column and beam. Mild steel bar of 4mm diameter was used as lateral ties at 25mm c/c spacing up to 167mm from the face of the beam in the column as per IS:13920:1993. Beyond this region, lateral ties of 4mm diameter mild steel bar were used with a spacing of 45mm c/c up to 83mm. Beyond this region, lateral ties of 4mm diameter mild steel bar were used with a spacing of 50mm c/c up to 250mm.

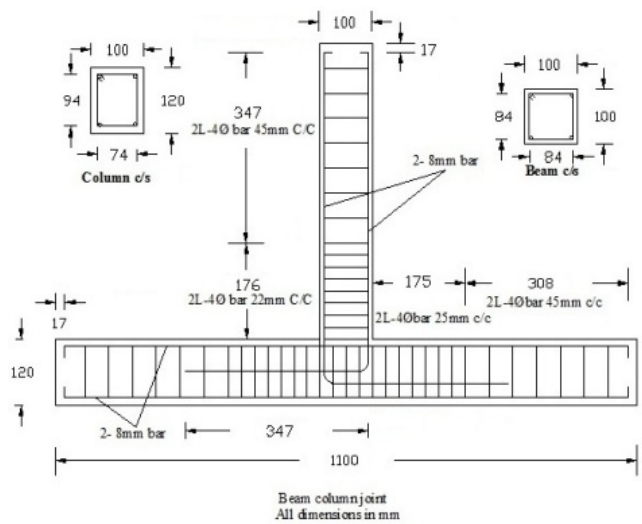


Fig. 2: Detailing of Beam-Column joint

Table 1: Detailing of all specimens

Specimen	Beam				Column			
	Effective Span(mm)	Cross Section (mm x mm)	Longitudinal Reinforcement	% of steel fiber	Effective span(mm)	Cross section(mm x mm)	Longitudinal Reinforcement	% of steel fiber
RCBC	540	100x 100	2-8φ top 2-8φ bottom	**0.75**	1100	100x 120	4-8φ total	**0.75**
SFRC	540	100x 100	2-8φ top 2-8φ Bottom	**0.75**	1100	100x 120	4-8φ total	**0.75**

In the beam, shear reinforcement of 2 legged 4mm diameter mild steel bar with a spacing of 22mm c/c was used near the beam column joint for a length of 176mm and 2 legged 4 mm diameter with mild steel bar a spacing of 43mm c/c was provided for the remaining part of the beam. The detailing of specimen is shown in Figure.2 and details of two specimens are shown in Table 1

4. METHODOLOGY

Strong Column-Weak Beam Principle:- Designing beam column joint is considered to be a complex and challenging task for structural engineers, since the joint region is subjected to very high horizontal and vertical forces as compared to the adjacent beams and columns. If the joint is not designed properly, the possibility of plastic hinge formation in column increases substantially. Hinge formation may occurs due to three reasons –

i) The collapse mechanism associated with hinges in the columns has a lower ultimate load.

ii) The energy absorption capacity of plastic hinges within the columns is normally less.

iii) Reason is chances of failure of column before the failure of beam increases leading to global failure which may be catastrophic.

Now one of the factor to ensure a strong column-weak beam in a ductile moment resisting framed structure is restricting the value of M_R. It is defined as the ratio of column to-beam flexural capacity and it is given by which should be greater than 1.2

$$M_R = \frac{\sum M_C}{\sum M_B}$$

Concrete mix design: - Beam-column joint specimens have been casted using design mix concrete. In order to arrive at the desired target strength, trial mix designs were carried out as per IS: 10262-2009.

Table 2: Results of mix design for M30 grade of concrete

Materials	Cement (kg)	Coarse Aggregate (kg)	Fine Aggregate (kg)	Water (lit)	Steel Fiber (kg)
Quantity per m3	450	1084.50	594.45	226.8	3.375
proportion	1	2.410	1.321	0.504	0.0075

5. FINITE ELEMENT MODELLING OF BEAM COLUMN JOINT

A finite element model of beam-column joint was done in ANSYS. Modeling is an important features in Finite Element Analysis. Improper modeling of the structures leads to the unexpected errors in the solution. Hence, proper care should be taken for modeling the structures. Finite Element modeling of beam-column joints in ANSYS consist of three stages, which are listed below. i) Selection of element type ii) Assigning material properties. iii) Modeling and meshing the geometry. After going through literature and after several initial trials, the elements for modeling various materials were finalized and the details of elements used are shown in Table. 3

Table 3: Details of Finite Element model

Sl. No	Material	ANSYS Element
1.	Concrete	Solid 65
2.	Steel	Link 8

The typical views of the reinforcements detailed as per IS 13920:1993 generated by the Ansys program are shown in Fig. 3

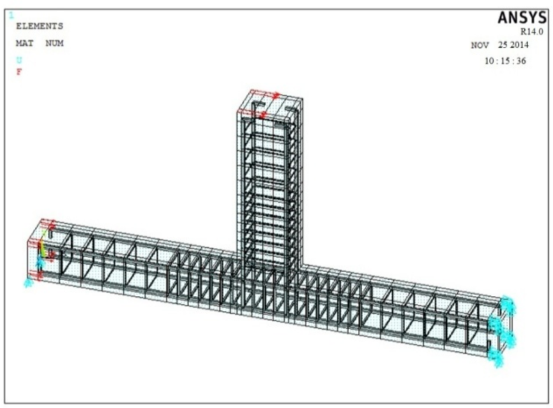


Fig. 3: Typical View of Reinforcement Detail as per Code IS 13920:1993

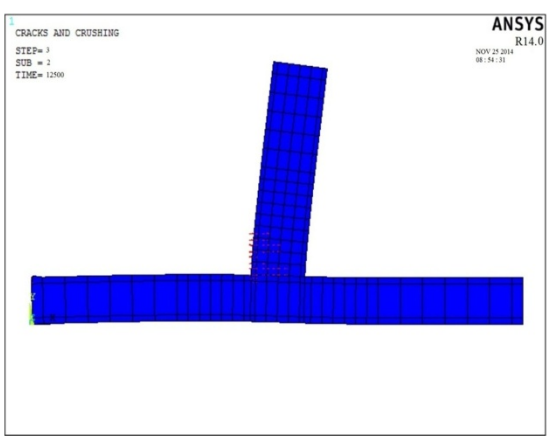


Fig. 4: First cracks occurred nearer to the BC joint

First crack occurred when the load reaches at 12.5KN. Initially the crack occurred at the joint region of the beam-column which is shown in the following fig. 4

Final crack occurred when the load reaches at 30KN. This crack occurred in the entire beam which is shown in the following fig.5

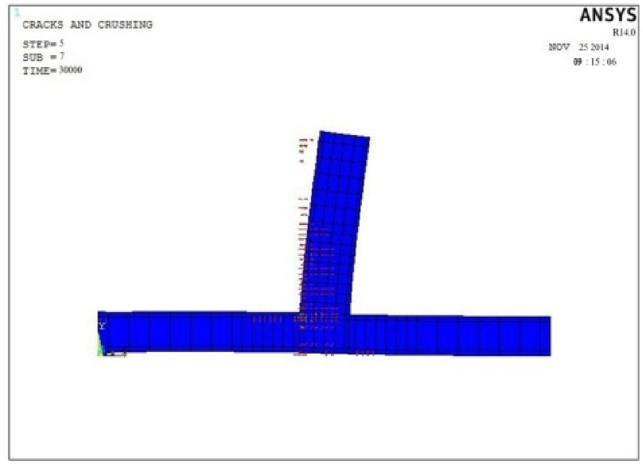


Fig. 5: First crack occurred nearer to the BC joint

A typical view of ultimate failure load and ultimate stresses of BC joint is shown in following fig.6. Failure occurred at the joint because maximum load & stresses come at joint.

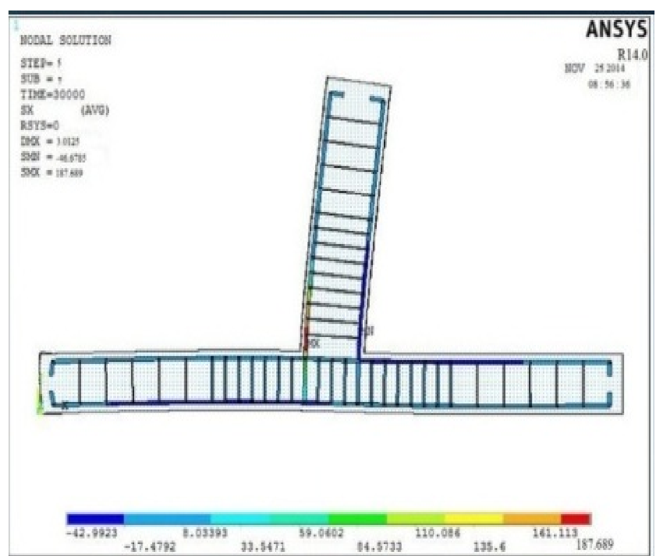


Fig. 6: Typical view of ultimate failure load and ultimate stresses

6. RESULT

Steel has an important role to make high performance concrete. SFRC has higher shear resistance, high tensile strength, greater toughness, high ductile, more durable, large bond stress in concrete, Using steel fiber , shear reinforcement can be reduce in joint region & minimize joint congestion.

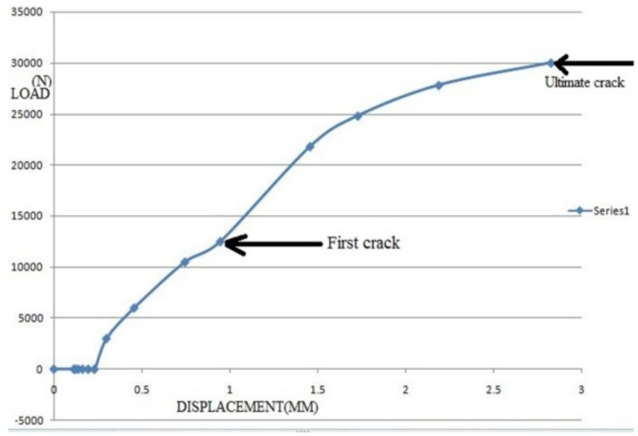


Fig. 7: Typical load-displacement curve

It increases behaviors such as joint integrity, structural ductility, and energy dissipation capacity, Reduces shrinkage crack, & micro cracks. Now it is seen that the first crack occurred under 12.5KN & final crack occurred under 30KN with RCBC which is shown in table. 4 & table.5 respectively.

Table 4: Results of RCBC joint under static loading up to first crack.

Displacement (mm)	Load (KN)
0.25	1.250
0.5	6.000
0.75	10.500
1.00	12.500

Table.5 Results of RCBC joint under static loading up to ultimate cracks.

Displacement (mm)	Load (KN)
1.25	14.000
1.50	22.000
1.75	25.000
2.00	26.500
2.25	27.500
2.50	28.500
2.75	29.000
2.90	30.000

7. ACKNOWLEDGEMENTS

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8. CONCLUSION

Four scale model of BC joint was considered. The first specimen which was made of RC was treated as control specimen. And remaining three specimens were casted by adding 0.25%, 0.50%, 0.75% of steel fiber. All specimens will be tested under cyclic loading to make a comparative study. The result will be compared in various plot like stiffness, energy dissipate and ductility. The resistance to pullout of steel fibers is important for efficiency. Pullout strength of steel fibers significantly improves the post cracking tensile strength of concrete. As an SFRC beam or other structural element is loaded, steel fibers bridge the cracks. Such bridging action provides the SFRC specimen with greater ultimate tensile strength more importantly, larger toughness, better energy absorption. The fibers play an important role in confining the materials.

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