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A Study on Strength and Ductile Behavior of Interior Beam-Column Joint Using Hybrid Steel Fibers

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Abstract- **In the frame structure, failures in beam-column joint mainly occur due to maximum bending moment and shear force. The reasons behind the failures due to conjection provision of reinforcement in the joints and concrete behave as brittle materials. This paper investigates the mechanical behaviours of interior beam-column jointsreinforced concrete and the application of hybrid steel fibrereinforced concrete composite (SFRC).In this study, three sets of interior beam-column joints were designed as per IS 1893code procedures for two bay five-story structures and detailed as per IS 13920 recommendations and based on IS 456 recommendations. The first specimen was made with normal concrete and reinforcement detailed as per IS 13920,the Second specimen was prepared with 1% of Steel fibre (0.5%Crimbed and % 0.5 Hooked end) and reinforcement detailed as per IS 456.The third specimen was moulded with 1%(0.5%Crimbed and % 0.5 Hooked end) fibre reinforcement detailed as per IS 13920. The model was developed by considering the 1/5thscale of the prototype and was tested under cyclic loading. The behaviour of the jointswas examined in terms of load carrying capacity, deflection, ductility and energy observation. The study concluded that increased of energy absorption capacity and ductility properties of the interior beam-column joint. The experimental results indicated that fibre reinforced concrete is an innovative solution to conventional confining reinforcement.**

Index Terms- **Interior beam-column joint, Load carrying capacity, ductility behaviour, Energy absorption capacity.**

1. INTRODUCTION

In general, the beam-column joint is the zone of intersection of beams and columns in the framed structures, which is subjected to a large amount of shear force and moment due to the fixity. Under the severe earthquake (seismic load), this shear and moment might be increased and it would lead to the failure of the beam-column joint. So, the entire structures would be destroyed. This joint should have adequate strength, stiffness and ductility to tackle the internal forces induced by the framing members due to heavy seismic load. This beam - column joint is classified into two types (interior and exterior beam-column joint) based on the location of the joint in the frame structures. In this paper, the study of strength and ductile behaviour of the interior beam-column joint using hybrid steel fibre was carried out. The model prepared for this study had two bay with five storeys and the scale adopted for this was 1/5th of the prototype. Totally, three specimens were prepared to analyse the interior beam-column joint. One specimen had prepared with the normal concrete by incorporating the steel reinforcement as per IS 13920. The second specimen had manufactured with fibre reinforced concrete which had 1% of Steel fibre with a crimbed and hooked end and the reinforcement was detailed as per IS 456. The third specimen was moulded with 1% fibre reinforcement detailed as per IS 13920. The cyclic loading (repetitive load) was given to test the specimens. The specimens were analysed to determine the deflections, load carrying capacity, ductility behaviour and energy absorption capacity.

2. TEST PROGRAM

2.1 Details of specimen

In fig1, the details of the prototype used for the study was shown. It had two bay and five storeys and each bay had 4.5 m length and 3.5 m width. Each storey had 3.0 m in height. The model had been prepared by using the scale of 1/5th of the prototype.

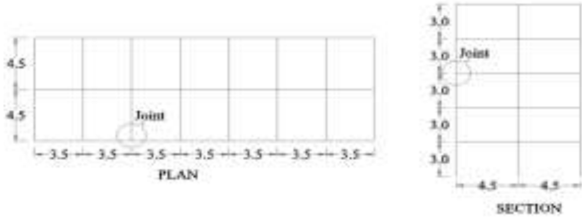


Fig 1 Plan and section for prototype

The reinforcement details of the interior beam-column joint as per IS13920 were shown in fig 2. Similarly, in fig 3 showed the reinforcement details of the interior beam-column joint as per IS 456. The column dimension of 230 mm x 120 mm and had been reinforced uniformly over the surface, with 8 numbers of 8 mm diameter bar. The beam hada cross section of 170 mm x 120 mm and it's lower side was reinforced with 3 numbers of 10 mm diameter bars. The beam and column have been provided with two-leggedstirrups of 6 mm diameterat 30 mm to 60 mm centre to centre spacing.

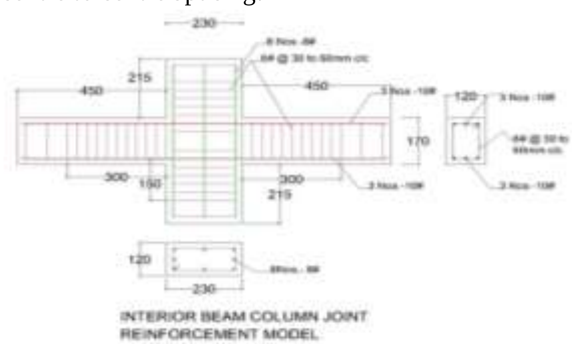


Fig 2 Reinforcement detail of Interior beam-column joint as per IS 13920

2.2 Material Properties

To prepare the beam-column joint specimen, as mentioned in the above, the materials such as cement, fine aggregate, coarse aggregate, potable water, steel fibres and reinforcement steel and the properties of the materials used had been given here.

(i) Cement

Cement used for the manufacturing concrete beam-columnspecimens was Ordinary Portland cement which is popularly known as OPC. The required tests on cement such as specific gravity test, fineness test and standard consistency test have been done and mix design as per IS10262 – 2007. The tests on cement were determined as per IS 576-1964and the specific gravity was found as 3.15 and the fineness of cement was determined as 4%. Standard consistency of the cement was found as 31%.

(ii) Water

The potable water available in the campus was used for mixing and curing of concrete. The potential of the hydrogen (pH) of the potable water was tested and the value was found as 7.2.

(iii) Fine aggregate

The river sand was used as fine aggregate to prepare the beam-column specimens. The sieve analysis had been done as per IS383 with the help of the IS 4.75 mm sieve and it came under the zone II.The specific gravity of fine aggregate was also determined and found to be 2.65. The surface moisture content was found as 0% and water absorption was also determined as 0.6%.

(iv) Coarse aggregate

The coarse aggregate used in this study were hard blue granite stones from quarries around Erode. The size of the aggregate used was 12mm which was stored in separate dust-proof containers. The specific gravity of coarse aggregate was determined and found to be 2.7. The surface moisture content was found as 0.5% and water absorption was also determined as 0.9%.

(v) Concrete

As per IS 10262 – 2007, the mix design for M30grade concrete was prepared with the help of the properties materials which were derived from the test conducted on the materials. The mix proportion was finally arrived at1: 1.02: 2.49 with the water-cement ratio of 0.4. to increase the workability of the concrete without affecting the strength of the concrete, the conplast 211 was used as an admixture.

(vi) Reinforcement Steel

The main reinforcement used for the preparation of the beam-column specimens was High Yield Strength Deformed bar (HYSD bar) and it belonged to Fe415 bar which had diameter 10 mm. The lateral tie and shear reinforcement were formed with the HYSD (Fe 415) bar of diameter 8mm.

(vii)Steel Fibres

The steel fibres used for this study had round crimped fibres and it is shown in fig 3. These fibres were supplied by Kasthuri Metal Mart, Pune, Maharastra. The properties of the fibres are shown in table.1. The length and diameter of fibre were 30 mm and 0.50 mm respectively. The aspect ratio of the fibre which is the ratio between the length and diameter used was 60. Modulus of elasticity and tensile strength of the fibre was 210000 Mpa and 1100 Mpa respectively.

Table.1Properties of fibres used

SI.No.	Parameters	Values
1.	Length	30mm
2.	Diameter	0.50 mm
3.	Aspect ratio	60
4.	Modulus of elasticity	210000 Mpa
5.	Tensile strength	1100 Mpa

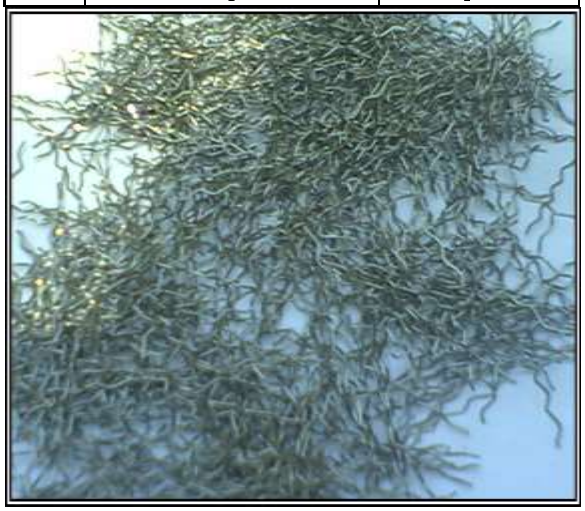


Fig 3 Round and Crimped Steel Fibres

2.3Specimen ID

The beam column joint specimen prepared with the help of the fibres and detailed as per IS13920 is named as ExF13920. The specimen made with the inclusion of the fibres and detailing with IS456 is classified as ExF456. Similarly, the specimen without fibres which is reinforced with IS13920 is named as Ex13920.

2.4 Details of the formwork

The specimens were cast with the help of the 12mm thickness film coated plywood sheet. The dimension of a mould for casting the beam region was kept as 450mm x 170mm x 120mm and the column portion contained the dimension of 600mm x 120mm x 230mm. The moulds were properly nailed to a base plywood sheet, in order to keep the alignment accurate. The inside of the mould was oiled properly before placing the concrete and the positioning of the steel reinforcement as explained earlier. Fig4 shows the formwork for casting the beam-column specimens.

Fig 4 Formwork for casting the specimens

2.5Casting of Specimens

As per the mix proportions, the concrete mix was prepared and three beam – column joint were cast. Initially, the fine aggregate and cement were mixed well and then, the coarse aggregate was added in the mix. Finally, 1% of steel fibres were added and mixed well together to produce two types of specimens (reinforcement as per IS13920 and IS456). The third specimen was prepared without the addition of the steel fibres and kept as a reference specimen. Fig 5 shows the mixing of concrete with the steel fibres. The prepared concrete was poured out in the mould up to 3 layers, after fixing the reinforcement for preparing the specimens. Each layer was tamped by using a tamping rod which is having 25 mm diameter throughout its lengthand 25 numbers of blows were given uniformly over the concrete surface. The curing of the casted specimens was done for 28 days.

Fig 5 Mixing of concrete with steel fibres

2.6 Experimental set up

The experimental set up for the testing of beam-column specimens were shown in fig 6. The loading frame was used to give the cyclic loading on the beam-column joint. Through the top of the column portion,the load was transferred with the help of the screw jack. A mild steel plate was kept at the top of the column to provide the uniform pressure over the column. The bottom of the beam-column joint was kept under the flat surfaced element (prism) to avoid the eccentricity of loading. The deflection of the beam-column joint was measured at the bottom of the beam portion by using the dial gauges.

Fig 6 Experimental setup SFRC Beam-Column joint

2.6.1 Mode of failure

The beam-column joint was subjected to several cycles of the repetitive loaduntil the failure of the specimen.The failure pattern of SFRC beam-column joint is shown in fig 7. Initially, the cracks were observed in the joint portion and laterally, it was spread over another portion. When the load was increased, the crack width was also increased and the decrement of load (reload) reduced the crack width. But, some amount of crack width was maintained and on every cycle, the crack width was kept on increasing till the failure of the specimen. After the completion of the few cycles of load, the beam–column joint was crushed at the weakest zone and spalling down. The initial crack width was measured for 3 specimens and tabulated in Table 1.

Table 1Initial crack width for all specimens

Specimen ID	Description of specimen	Initial crack width in mm
IN13920	Interior beam – column joint without fibres and detailing as per IS13920	12
INF456	Interior beam – column jointwith fibres and detailing as per	15
INF13920	Interior beam – column joint with fibres and detailing as per IS13920	21

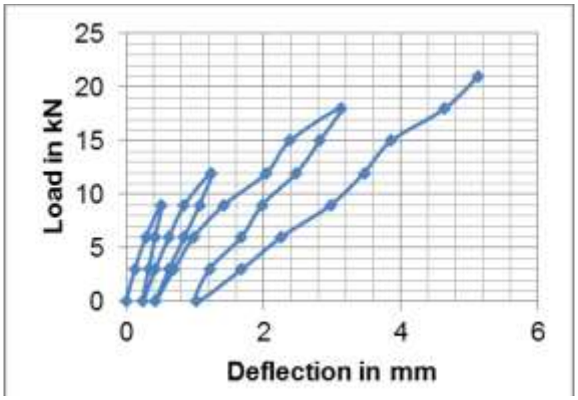
Fig 7Failure of SFRC Beam-Column Joint

2.7 Results and discussion

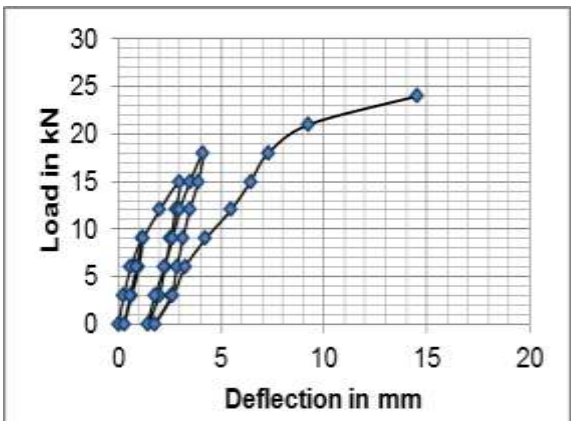
Based on the results from a test carried on the interior beam-column joint specimens, the behaviour and properties of the specimens were derived. Various graphs were plotted by using the values obtained.

The deflections of all specimens were measured corresponding load cycles such as loading and unloading. The graphs were plotted for all the specimens and shown in fig.8. The specimen ExF456 had been subjected 2 cycles and it failed at the 3rd cycle of loading. It reached the maximum value of deflection as 2.42mm for a maximum load of 18 kN. The specimen Ex13920 (control specimen) was subjected to 3 cycles of loading and it failed at the 4th cycle of loading. The maximum load reached by this specimen is 21kN and corresponding deflection value is 5.12mm. In a similar manner, the specimen ExF13920 reached the maximum value of load as 24kN and the respective displacement measured as 14.52mm.The comparison of breaking load of specimens is shown in fig.9. The maximum deflection of each load cycle was noted down for all the specimens and the variation of the maximum deflection values had been plotted as shown in fig.10. The energy absorption is generally defined as the product of the force and displacement. Thus, the energy absorption of each cycle of the load for all the specimens was monitored and plotted as a curve as shown in fig 11.

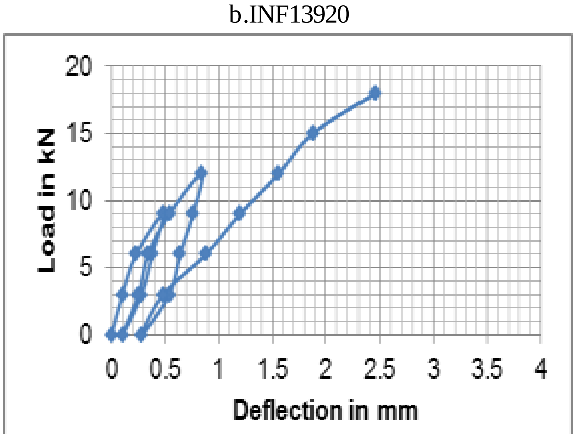
The IN13920 specimen (control specimen) has 3 kN more load carrying capacity than the INF456 specimen and the specimen INF13920 has more 3 kN load carrying capacity than the specimen IN13920. Similarly, the cumulative energy absorption of the specimen INF13920 has more value than the other specimens. The cumulative deflection of the INF13920 was also more when compared to the other two specimens. This is because of the more load carrying capacity of the specimen INF13920 which is leading more deflection. Due to the addition of the fibres, the load carrying capacity of the specimens was increased. Thus, the specimen INF13920 showed good performance with respect to all points of view. So, the inclusion of the fibres (1%) into the beam-columnjoint specimen increases the ductility and strength of the beam-column joint.



a. IN13920



b.INF13920



c. INF456

Fig.8 Load Vs Deflection graph for interior beam-column joint under cyclic load

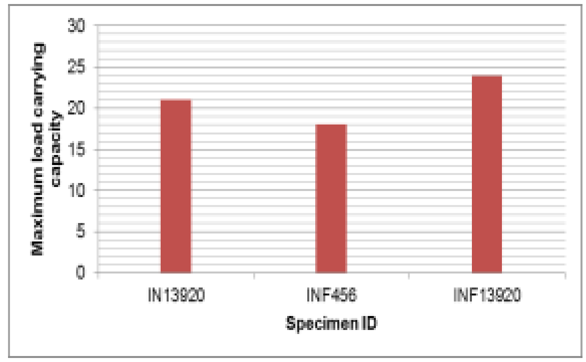


Fig 9Comparison of the load carrying capacity of specimens

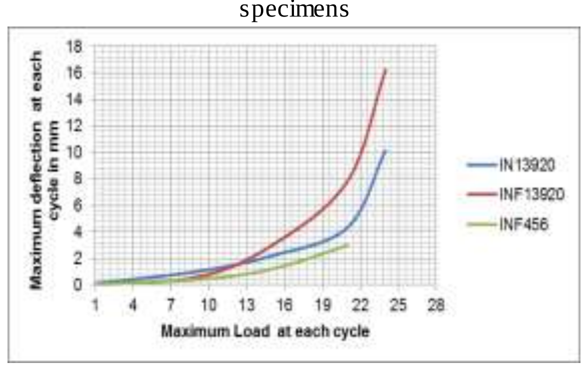


Fig.10Variation of maximum deflection w.r.t. maximum load at each cycle

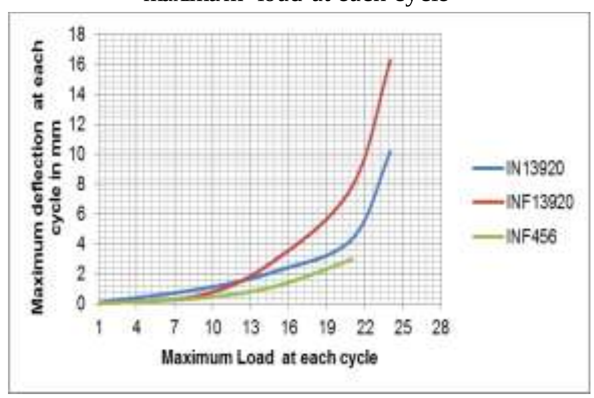


Fig 11 Cumulative deflection of specimens w.r.t. load cycle

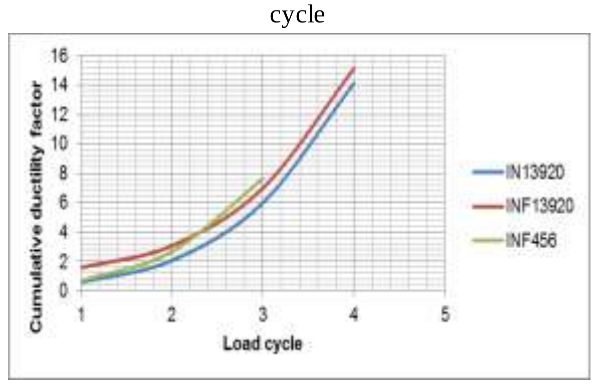


Fig.12 Cumulative ductility factor of specimens w.r.t. load cycle

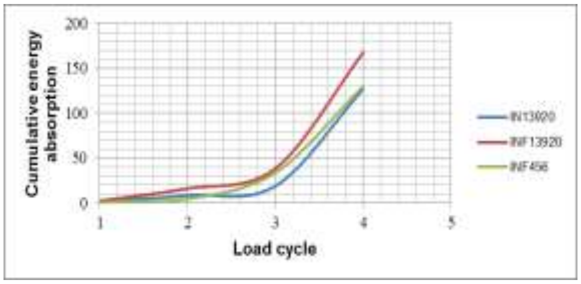


Fig.13 Cumulative energy absorption of specimens w.r.t. load cycle

3. CONCLUSION

- The addition of fibers in the beam-column joint specimen increases the load carrying capacity.
- The ductility factor also increased with the inclusion of fibres in the beam-column joint specimen.
- The energy absorption capacity of the beam – column joint increaseddue to the introduction of the fibres.
- The reinforcement detailing as per IS456, reduced the load carrying capacity, ductility factor, energy absorption and increased the stiffness degradation of the beam-column joint.
- Thus, the addition of the fibres and detailing of the reinforcement with IS13920 increased the strength and ductility characteristics of the beam-column joint.

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