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Research paper

Rehabilitation of Beam Column joint using Steel Fibrous Concrete

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Abstract

An experimental study was conducted to compare the structural behavior of beam column joint before and after rehabilitation by using fibrous concrete with steel fibers as a strength enhancer material. Two specimens were examined in this study out of which one was designed according to IS 456: 2000 (control specimen) codal provision and another one was designed according to IS 13920:2016(ductile specimen). Both the supports at top and bottom faces of the column were hinged, and the load was applied on the edge of the beam. The parameter observed during the experiment was Load- deflection response for both control and rehabilitation specimens. The ultimate load carrying capacity for rehabilitated controlled specimen increased by 36.6% in comparison with controlled specimen, and the ultimate load carrying capacity for rehabilitated ductile specimen increased by 62.3% in comparison with ductile specimen. It has been observed that steel fiber reinforced concrete can enhance flexural strength, ductility and crack arrest.

Keywords: *Beam column joint, Ductility, Flexural strength, Rehabilitation, Steel fibers*

1. Introduction

The Beam Column joint (BCJ) is critical zone in reinforced concrete frame. Especially, when they are subjected to the earthquake forces its behavior has a significant influence on the response of the structure. The BCJ plays a prominent role in transfer of gravity loads and energy dissipation. Generally, when earthquake occurs, joints are severely damaged which makes the structure weak.
Buildings must be designed to withstand the earthquakes to reduce the damage on the structure after the earthquake. To resist lateral force, the ductile detailing must be provided in the reinforced concrete moment resisting frame. Inadequate transverse shear reinforcement in BCJ has proved to be deficient and after earthquake joint will experience brittle shear failure. So, for a better performance of a BCJ, ductile detailing is important under earthquake loads.

The process of restoring the structures to service level for what it was designed previously is called as Rehabilitation. Materials that are used for rehabilitation are fibers made of steel, carbon, glass, polypropylene. With the application of new material alternatives like steel fibers, properties like tensile strength, flexural strength, shock resistance, fatigue resistance, ductility and crack arrest can be improved in BCJ.

A structure designed using IS-456: 2000 [1] does not provide sufficient safety and stability during earthquakes as failure occurs in brittle nature due to insufficient ductile reinforcement. In order to withstand earthquake forces, a structure must be designed using IS-13920: 2016 [2] which provides necessary ductile reinforcement.

Yung-Chih [3] investigated on the full scale one-way Beam - column joint. The BCJ both interior and exterior the RC jacketing were done. The results obtained proved that the exterior has given better seismic performance. The jacketing of BCJ has improved the stiffness, strength and ductility. Romanbabu [4] investigated on the three one third scaled specimens that are detailed as per IS-13920. The three specimens out of which one is conventional, and other two with the in-cooperation of polyproline and steel fibers. The results concluded that the specimens incorporated with fibers had more stiffness, ductility compared to conventional. Bindhu [5] experimented on the four one third specimens two detailed with IS-456 and SP-34 and other two with IS-13920 and tested under reverse cyclic loading. Increase in Column axial load will improve the joint stiffness and load carrying capacity. The results concluded that the IS-13920 has more energy absorption capacity than the other specimens. Vikrant [6] studied on the performance of steel fiber in reinforced concrete, they have the sustainable and long-lasting nature so they are widely used, the addition of steel fibers will reduce the workability to solve this problem, superplasticizers must be added without effecting the properties of concrete. Usha [7] conclude that after the addition of steel fibers to concrete, the failure mode changed from brittle to ductile, so steel fibers can be used to increase tensile strength and achieve ductility in the places where reinforcement cannot be used. Chaitanya Kumar [8] compared the effect of glass and steel fibers in concrete and concluded that by addition of steel fibers the strengths like compressive, flexural and split tensile are increasing linearly with increase of fibers, but up to 1% addition of glass fiber the strength is increasing and from 2% it is decreasing.

2. Description of the Specimen

Two, one third scaled specimens of BCJ are designed as per IS-456(2000) and IS-13920(2016). The specimen designed according to IS-456 is the Control Specimen(CS) and the specimen designed according to the IS-13920 is the Ductile Specimen(DS). The cross-sectional dimensions of the two specimens was same(Table:1). The column designed was 1000 mm in length and the cross section provided was 150mm x 200mm, while for the beam is of length 375mm with cross-section of 200mm x 150mm. IS-456 code specified specimen has 4 number of high yield strength deformed bars of 16mm diameter was used as reinforcement in column and for the beam 3 bars of 16mm on top and 2 bars of 12mm at bottom. The 7 No's of 8mm Dia. was used as lateral ties with spacing of 150mm c/c spacing in Column and 4 No's of 8mm Dia. with spacing of 130mm c/c in beam. In IS-13920 specified specimen has 4no's of 16mm Dia. was used as reinforcement in the column and 3 bars of 16mm on top and 2 bars of 12mm at bottom of the beam. The 15 o's of 8mm Dia. used as lateral ties 150mm c/c spacing in column and 9 No's of 8mm Dia. at 130mm c/c in beam. The detailing can be clearly seen in Figure:1&2.

Table 1: Dimensions of all specimens

Column dimensions(mm)			Beam dimensions(mm)		
Length	Width	Depth	Length	Width	Depth
1000	150	200	370	150	200

Design mix calculations were made as per Is 10262-2009, 53 grade ordinary Portland cement was used, coarse aggregate and fine aggregate confirming to zone-II was used. The specific gravities of cement, fine aggregate and coarse aggregates are 3.15, 2.324, 2.782. Target mean strength for M25 grade is 31.6 N/mm^2. The reinforcement details are shown in Table 2 and Table 3.

Table 2: Reinforcement detailing of column

S. No.	Specimen	Longitudinal reinforcement			Transverse reinforcement		
		No. of bars & Dia.	A_{st} (mm^2)	P_t (%)	No. of bars& Dia.	A_{st} (mm^2)	P_t (%)
1	CS	4-16mm	804 .24	0.0 27	7-8	351. 85	0.018
2	DS				15-8	753. 98	0.025

Table 3: Reinforcement detailing of beam

S.No.	Specimen	Longitudinal reinforcement			Transverse reinforcement		
		No. of bars& Dia.	A_{st} (mm^2)	P_t (%)	No. of bars& Dia.	A_{st} (mm^2)	P_t (%)
1	CS	Top r/f 3-16mm Bottom r/f 2-12mm	603.18	0.020	5-8	251. 3	0.00 84
2	DS		226.19 0.	0.007 5	9-8	452. 34	0.01 5

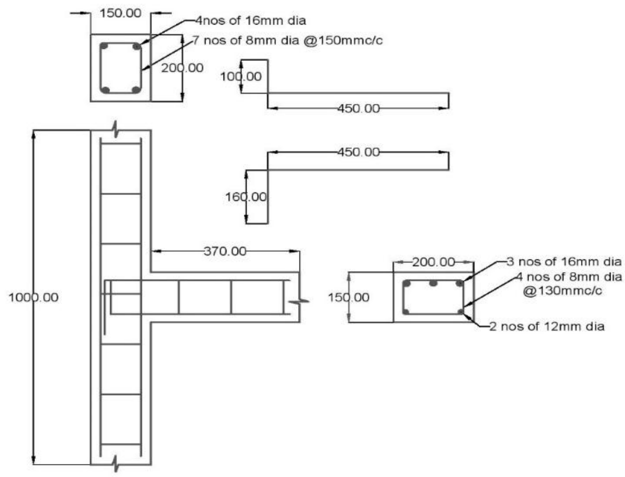

Figure 1: detailing of beam column joint using IS 456

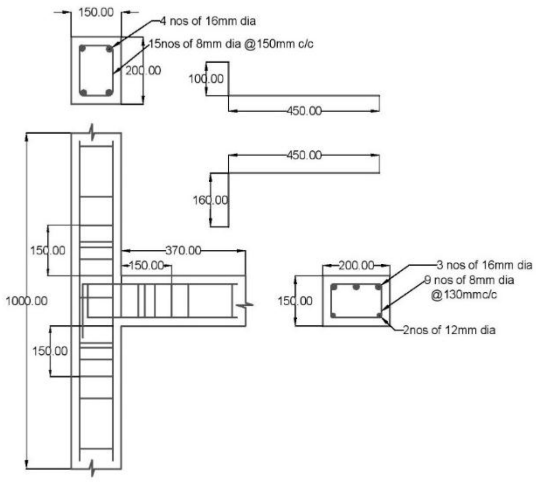

Figure 2: Detailing of beam column joint using 13920

3. Loading Arrangement

The schematic diagram of test-setup is shown in figure 3. The loading frame of 50tons capacity was used for testing the specimens. The column was placed vertically in the setup. An axial load of 20tons was applied to the column to represent gravity load. 2 hinge supports are used on both sides of the columns, the beam in BCJ is adjusted in such a way, that the hydraulic jack can apply load at the end of the beam. LVDT is arranged so as to get the load and its respective deflection of the beam.

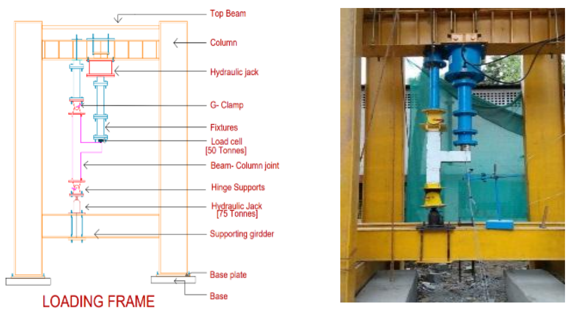

Figure 3: Beam column joint setup in loading frame.

3.1. Testing of Control Specimen

After the setup was completed in the loading frame, the control panel is made ready for obtaining results. With the help of loading cell, the load is gradually applied on the specimen, the displacements were recorded by LVDT, for a load of 12.4kN at a deflection of 26.58mm the first crack was observed. After the initial crack, the load again applied on the specimen and the maximum load taken was 18.3kN at a deflection of 33.14 mm.

3.2. Testing of Ductile Specimen

The testing arrangement of the specimen is shown in the Fig4, the load was applied gradually on the specimen. It was observed that for a load of 19.45 kN and at displacement of 28.78 mm, initial crack was start propagating at the intersection of beam column joint. For an ultimate load of 26 kN and at a deflection of 32.04 mm, cracks were started widening.

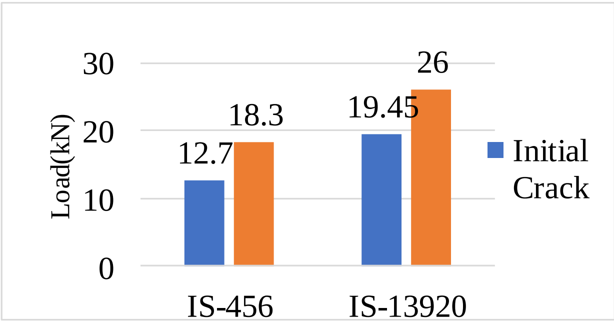

Figure: 4 Results of BCJ before Rehabilitation

3.3. Rehabilitation of the Specimen

The zone(place), where cracks were propagated is chipped off, as shown in Fig.5 the specimen is made free from loose particles after chipping off the cracked zone of concrete, then cement mortar is poured on the surface of concrete, where new concrete will contact older one for bonding. Then the rehabilitation material is added (steel fibers) to concrete in 2% of Volume fraction (V_f). Then the concreting is made to fill the zone of chipped area. Specimens were made ready for testing after the required time of curing period.

Figure 5: Specimen after chipping

Figure 6: Specimen after rehabilitation

Figure 7: fibrous concrete

3.4. Testing of Rehabilitated Controlled Specimen

After the process of rehabilitation using fibrous concrete, and curing the specimens for the required time, the specimens have been tested under the same test setup as before. The first crack was observed at a load of 17 kN for the deflection of 26.32mm. the ultimate load was 25kN for a displacement of 32 mm(Figure:8)

Figure 8: Control specimen before and after testing

3.5 Testing of Rehabilitated Ductile Specimen

After the process of rehabilitation using fibrous concrete, and curing the specimens for the required period, the specimens have been tested under the same test setup as before. The first crack was observed at 30.5 kN with a deflection of 17.27 mm and the final crack was observed at 42kN at a deflection of 30.61 mm(Figure:9).

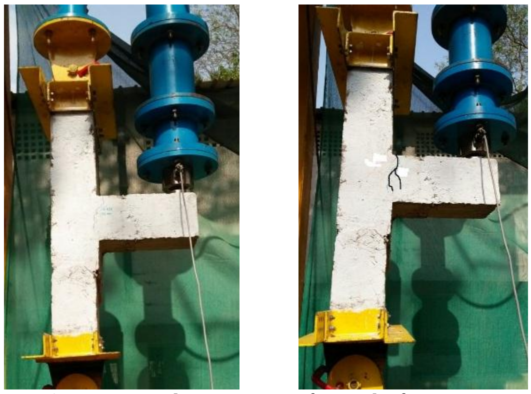

Figure 9: Ductile Specimen Before and After Testing

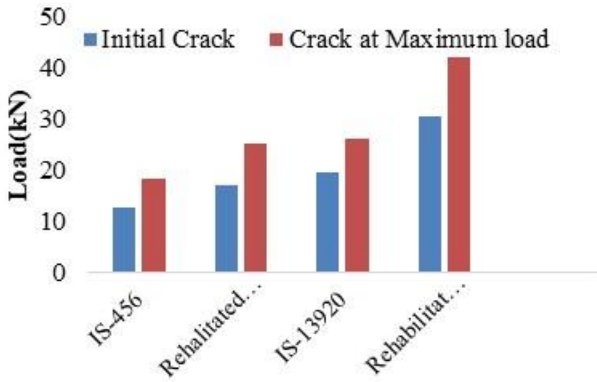

Figure 10: Crack Loads comparison

3.6 Load vs Deflection

The load carrying capacity of rehabilitated specimens were increased 36.6% for IS 456 & 62.3% for IS 13920. The maximum load taken by the conventional IS-456 was 18.3kN at deflection 25mm. The maximum load taken by Rehabilitated IS-456 was 25.8kN at deflection of 42.6mm(Figure:11). The maximum load taken by the conventional IS-13920 was 26kN at deflection 33.04mm. The maximum load taken by Rehabilitated IS-13920 was 21kN at deflection of 9.17mm(Figure:12).

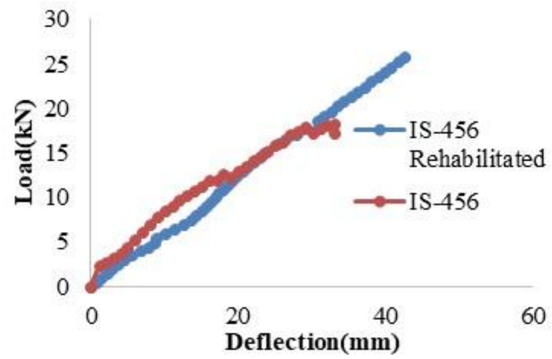

Figure 11: Load Vs Deflection graph of IS-456

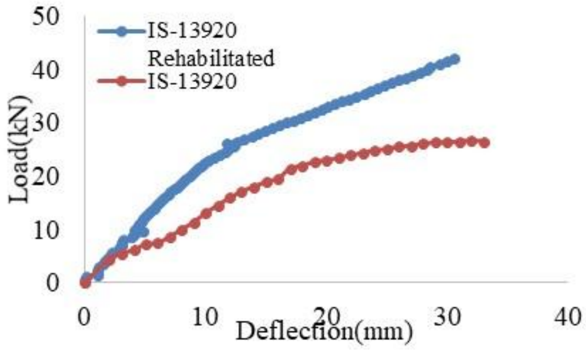

Figure 12: Load Vs Deflection graph of IS-13920

4. Conclusion

In this experimental study of beam-column joint, 2 scaled models were designed by using IS 456 & IS 13920, these specimens were tested under point load until the ultimate load is reached and the propagated cracked zone of concrete was chipped off and rehabilitated by using steel fibrous concrete. And again, these rehabilitated specimens were tested under same loading condition, and the results were compared conclusions were drawn

- The addition of fibers played an important role in arresting and delaying propagation of crack.
- The load carrying capacity of rehabilitated specimens were increased 36.6% for IS 456 & 62.3% for IS 13920.
- Using steel fibrous concrete near BCJ failure mode changed from brittle to ductile.
- Based on the interpretation of results, the following
- This steel fibrous concrete can be used in critical areas for increasing tensile strength and to achieve ductility.
- This fibrous concrete is used for retrofitting and rehabilitation of structures so as to increase strength and ductility.

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