Strengthening of beam - column joint with steel fibre reinforced concrete under seismic loading

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Abstract. Earthquakes not only kill the human beings but the structures too. Considering this above fact, there is a necessity to take care of the beam column joint region in a structure. Under seismic excitation, the bar segment joint district is subjected to even and the vertical shear force extents are normally commonly greater than those in the adjoining bits of the structural segments. In the event that the joint is not precisely nitty gritty, the shaft segment joint may end up plainly frail. To keep this, an adequate control ought to be given in the joint area. The seismic examination and outline technique ought to be utilised as a part of the plan of the building structures and their segments ought to be recommended in the segment. The building structures incorporate finish sidelong and vertical drive opposing frameworks fit for giving satisfactory quality. Stiffness and the vitality dissemination ability to withstand the outline ground movements inside the recommended furthest reaches of twisting and quality request. The plan ground movements are accepted to happen along any even headings of a building structure. This work focuses on behaviour of M20 concrete in beam-column joint subjected to seismic loading, by using steel fibre (1.5%). The specimens detailed as per IS: 456-2000 and IS: 13920-1993 were casted and tested under cyclic and reverse cyclic loading. The parameters analysed were ductility, energy dissipation, load v/s displacement curve, beam-column reinforcement strain and crack pattern. From the experimental investigation, it is found that the fibre reinforced beam-column joint with fibre (1.50% of steel fibre) performs better ductility, load carrying capacity, energy dissipation and strength by 10% more than conventional reinforced beam-column joint.

Keywords: Fibre reinforced concrete, Seismic loading, Beam-column joint.

1. Introduction

1.1 General

Seismic tremors show a risk to open security and welfare in a huge segment all over. We can't stop tremors however we can shield ourselves from them, as "quakes don't slaughter individuals, yet the structures do". The conduct of fortified solid minute opposing casing structures in late seismic tremors everywhere throughout the globally highlighted the outcomes of meagre execution of bar segment joints. Shaft section joints in a strengthened solid minute opposing casing are urgent zones for an exchange of burdens viable between the interfacing components (i.e. pillars and segments) in the
structure. In the investigation of reinforced concrete frames, the joints are for the most part accepted as inflexible [1].

1.2 Reinforced cement concrete
Consistently flexibility of concrete is 8% to 15% of its compressive quality. This inadequacy has been overseen over various decades by using a plan of fortifying bars (rebars) to make invigorated strong so that strong basically contradicts compressive tensions and rebars restrict flexible and shear stresses. The longitudinal rebar in a column restricts flexural (versatile uneasiness) however the stirrups, wrapped around the longitudinal bar, contradict shear stresses. In a portion, vertical bars restrict weight and catching burdens while ties contradict shear and offer detainment to vertical bars. With the use of steel strengthened, strongly makes for a conventional composite material with expansive use in the improvement business. Be that as it may, steel bars in the fortified strong give resistance against weight just locally. Softens up fortified strong people grow transparently until encountering a rebar. The necessity for multidirectional and immovably isolated support for bond rises. It's here the point the use of fibre fortress comes into for course of action [1,2]

1.3 Fibre Reinforced Concrete (FRC)
Fibre reinforced concrete is an active mix that consists of shortened, unattached fibres that are reliably spread and heedlessly orchestrated. The mix measured as a rate of the total volume of the composite (cement and fibre) named Vf. Vf commonly goes from 0.1 to 3% point of view extent (l/d) is learned by parcelling fibre length (l) by its expansiveness (d). Fibres with a unrounded cross range use comparable width for the figuring of point ratio [3]. The essential part of the strands in solidified cement is to alter the breaking system. By modifying the breaking system, the full-scale splitting ends up plainly miniaturised scale splitting. The breaks are littler in width, in this manner lessening the penetrability of cement and a definitive splitting strain of the solid is upgraded. The filaments are equipped for conveying a heap over the crack. The rate of steel fiber utilised is around 1.5% is taken consistent for every one of the examples, the steel fiber length ranges 30mm, and viewpoint proportion runs around 60. The ratio of polypropylene fiber is changed from 0.2% and 0.4%. The length is around 20 mm, and the perspective portion is around 2500.

1.4 Beam-column joint
The joint is described as the piece of the section inside the significance of the column frames. In a contradicting edge, three sorts of joints can be identified viz. inside joint, outside joint and T joint showed up in Figure 1. When four bars layout into the vertical appearances of a segment, the joint is called as an inside joint. When one column traces into a vertical face of the segment and two unique shafts diagram from contrary headings into the joint that is an outside joint. Exactly when a column each edges into two adjacent vertical faces of a fragment, then the joint is called as a T joint.
The functional requirement of a joint, which is the zone of convergence of beams and columns, is to empower the associating individuals to create and maintain their definitive limit. The request on this limited size component is constantly serious, particularly under seismic stacking. The joints ought to have sufficient quality and firmness to oppose the inside strengths invited by the confining individuals.

2. Details of specimen
The test specimen was reduced to one fourth scale to suit the loading arrangement and test facilities. Four numbers of 8 mm diameter bars were used for main bars in column and 3 nos. of 8 mm diameter were used for top reinforcement and 2 nos. of 8 mm diameter were used for bottom reinforcement in beams. The dimension of beam was 110×90 mm and that of column was 90×90 mm[4].

2.1 Fibre
The steel fibres used is shown in Figure 2. The properties of fibres are given in Table1.

![Figure 2. Steel Fibres.](image)

### Table 1. Properties of fibres

| Types of mix            | l/d ratio | Corresponding strength | Corresponding toughness |
|-------------------------|-----------|------------------------|------------------------|
| Plain concrete with randomly dispersed fibres | 0         | 1.00                   | 1.00                   |
|                         | 25        | 1.50                   | 2.00                   |
|                         | 50        | 1.60                   | 8.00                   |
|                         | 75        | 1.70                   | 10.50                  |
|                         | 100       | 1.50                   | 8.50                   |
2.2 Concrete

The amount of aggregate added to the concrete is reduced while adding fibres. The conventional strength of concrete and concrete with steel fibre at 28 days was determined by compression test on cubes of size 6 inches × 6 inches × 6 inches. The Table 2 shows the mix ration and Table 3 shows the specimen details for cubes of various proportions of the fibre with concrete. The type of test specimen and percentage of the fibre comparing to mixes [11, 12].

| Specimens ID | Description of test specimens | % of Fibre |
|--------------|--------------------------------|------------|
| O1 and O2    | Normal concrete               | ----       |
| S1 and S2    | Normal concrete               | ---        |
| F11 and F12  | Fibre Reinforced concrete     | 1.50%      |

Table 4 shows the compressive strength for cubes of various proportions of fibre with concrete. We can conclude that concrete with steel fibre (1.5%) has more compressive strength comparing to other mixes.

| Specimen | Type            | Compressive strength of cube N/mm² |
|----------|-----------------|-----------------------------------|
| O1,O2    | Normal concrete | 28.02                             |
| F11,F12  | N.C + SF (1.5%) | 36.22                             |

2.3 Steel

The main reinforcement used for the specimen was tor steel of diameter 8 mm, shear reinforcement was mild steel of diameter 3.3 mm. Specimens of 300 mm length were cut out and tested in computerized. The reinforcement details and reinforcement cage of the ordinary joint are consider. The capacity of reinforcements is shown in Table 5.

| Description | Yield load (kN) | Ultimate load (kN) | Ultimate stress (N/mm²) | Yield stress (N/mm²) |
|-------------|-----------------|--------------------|-------------------------|----------------------|
| 8 mm bar    | 21.00           | 26.9               | 353.09                  | 417.73               |
| 3.3 mm bar  | 1.42            | 2.9                | 341.36                  | 166.00               |
3. Reinforcement details
The rate of steel fibre in the bar and segment are 2.539 and 2.482 separately. The fundamental fortification given in the bar was 8 mm width bars, 3 Nos at the top and 2 Nos at the base. The stirrups are 3.3 mm width bars at 20 mm c/c for a separation of 2d, i.e. 220 mm from the substance of the segment and at 40 mm centre to centre for the rest of length of bar. The fortification subtle elements and support pen of the test example with steel fibre appear in Figure 4.4. The rate of steel in pillar and section are 2.539 and 2.482 separately. The fortification confines were put in the moulds, and cover amongst enclosure and shape gave 10 mm. The stirrups are 3.3 mm distance across bars at 40 mm c/c separating and 20 mm c/c middle segment of bar and section. The pressure or pressure in any bar at any section is created on either side of the part by a suitable improvement length. The first bars of the segment must be proceed up either inside or outside the support of floor shaft which outlines because of this section. It is essential that the width of section more than the width of the bar. The support is set and situated entirely the necessity in the auxiliary member [5].

4. Instrumental arrangement
All the specimens were tested in a reaction frame of 50 tonnes capacity. The Figure 3 describes the instrumental arrangement. A hydraulic jack were adopted for apply the load at the free end of the beam in both upward and downward direction individually [6].

Figure 3. Test setup for cyclic load.

To record the heap correctly a proving was utilised. The heap is connected cyclic and turns around cyclic and measured for each 5mm diversion. The avoidance of the pillar at the purpose of stacking amid test was measured, such as 5 mm, 10mm and 15 mm individually. Inversion stacking is noted for each lessening in redirection. Every specimen was tried in a response edge of 50 tons limit.

4.1 Loading history
The exterior beam column joint specimen was regulated to cyclic loading and reverse cyclic loading simulating earth quake loads. The displacement sequence consists of 5 mm, -5mm, 10 mm, -10 mm, 15mm, -15mm, 45mm and -45mm. Each displacement level is indicated in dial gauge and corresponding loads are noted from proving ring. In the first cycle, beam was loaded gradually up to 5 mm deflection and then unloaded. and beam was loaded gradually up to -5 mm deflection and then unloaded the second cycle, beam was loaded gradually up to 10 mm and then unloaded and beam was loaded gradually up to -10 mm and then unloaded similarly each cycle of load is applied. The displacement history plotted as shown in Figure 4.
5. Results and discussion

5.1 Load vs displacement cycle

The load Vs displacement cycle is drawn for every specimen, the load is noted for 5mm displacement, for each cycle and reverse cyclic of loading. The reversal of loading is noted from the proving ring. For each samples were tested every displacement of 5 mm load in each cycle are noted the hysteresis loop for all the specimen. The variation of load Vs displacement cycle for various beam column joints with various combination at beam and displacement. The area for each hysteresis loop was calculated. The parameter of load Vs displacement cycle shown in Figure 5, Figure 6 and Figure 7 for O1,O2, S1,S2 and F11, F12 respectively.

![Figure 4. Displacement history.](image)

![Figure 5. Load Vs Displacement cycle for O1,O2.](image)

![Figure 6. Load Vs Displacement cycle for S1,S2.](image)
5.2 Energy dissipation

The energy dissipated at each cycle for various specimens is shown in Figure 8. The energy dissipation capacity is calculated using the enclosed area of the load deformation curve during each cycle of loading (i.e. area of each hysteresis loop).

5.3 Beam and column reinforcement strain

To compute the strain, demec strain gauge was arranged in the beam lower reinforcement and in the column top outer face reinforcement. The gauge length 100 mm was maintained for all the specimens to fix the strain gauge.[7]

5.3.1 Beam bottom reinforcement strain. The displacement, cycle of various specimen are listed below for the specimen O2, S2 and F12 the yield strain occurs at 5 mm (1st cycle) and ultimate strain at -30 mm (4th cycle). The stress condition may be the strength of concrete in the tension zone is greater than the strength of steel reinforcement the tensile resistance of concrete is lost due to formation of initial crack the steel may not be able to take over the tension which was earlier resisted by the concrete a failure will acquire suddenly with the concrete in the tension zone cracking and the steel fractured almost simultaneously. The Figure 9 shows the beam bottom reinforcement strain, cycle of various specimen are listed below for the specimen O2, S2 and F12.
5.3.2 Column Reinforcement Strain. Demec strain gage was utilised to gauge the strain in column top external support. For the specimen O2, the yield strain happens at 10mm (second cycle), and ultimate strain endures 30mm (fourth cycle). In the example F12, yield strain occurs at 5mm (first cycle), last encounter - 30mm (fourth cycle). The specimen S2 yield strain happens at -5mm (first cycle), extreme resist 30mm (fourth cycle). In any column had a bigger cross sectional territory that needed for load support, the base rate of steel be founded on the zone of cement required to oppose the immediate anxiety and not upon the certain region the base number of bars given in a segment be four in rectangular column[8]. The longitudinal reinforcement by transverse connections to provide a limitation against out words clasping of each of the longitudinal bars the closures of the transverse connections the legitimately secured. The Figure 10 demonstrates the Column beat reinforcement strain cycle of different example is recorded underneath for the specimen O2, S2 and F12.

5.4 Load vs displacement curve
The Figure 11 shows Load v/s Displacement at each cycle for various specimens and the load v/s displacement curve during each cycle of loading.
5.5 **Ductility**
Ductility is an important characteristic of any structural element. It is described as the capacity of a structural element to undergo deformation beyond yield without losing much of the load carrying capacity. Any type of brittle failure should be avoided, as it does not show warning before failure. If the structure possesses sufficient ductile behaviour, it will be able to experience large deformation near ultimate loads. The amount of this inelastic deformation is proportional to the amount of ductility of the member. Ductility has generally been measured by a ratio known as ductility factor. It is usually expressed as a ratio of deflection ($\Delta$) at failure to the corresponding yield, as shown below.

$$\text{Displacement ductility factor } \mu = \frac{\Delta_u}{\Delta_y}$$  \hspace{1cm} (1)

Increase in deformations after reaching ultimate load condition was not considered during experimentation. Hence the deformations at ultimate load have only been considered. The ductility for the various proportions were calculated and presented. It is observed that the ductility property for the beam column joint with fibre mix is more comparing to other specimens[9,10].

5.6 **Crack pattern**
In the beam-column joints, compression and tension developed in joint region during cyclic loading and the bond between concrete and reinforcement were reduced consequently. The first crack occurred near the beam-column joint and with further increase in loading, the cracks propagated and initial cracks started widening. The crack pattern of the specimens will be discussed as below. Figure 12 shows the crack pattern for ordinary joint. In this the first crack occurred vertically at 7mm deflection in second cyclic loading. When load is applied at the bottom of the beam. The second crack occurred at 10 mm deflection at third reverse cycle of loading. The third crack occurred diagonally at beam column joint at 25 mm deflection at fourth cyclic of loading. The major crack occurred at joint region at 40mm deflection at fifth cyclic of loading. The Figure 13 shows the crack pattern for the seismic detailed joint. In this joint, while applying second cycle loading, the first crack occurred vertically at 5mm deflection in second cyclic loading. The second crack occurred at -15 mm deflection at third reverse cycle of loading. The third crack occurred diagonally at beam column joint occur in 30 mm deflection at fourth cyclic of loading. The crack pattern for the seismic detailed joint of major crack occurred at joint region in 45 mm deflection at fifth cyclic of loading. In this joint the crack width is small compare to ordinary joint, so it behaves better than ordinary joint.
By comparing the Figure 12 to Figure 14, we can observe that the width of the crack is reduced and the ductility is increased. From the Figure 14 the second, third, fourth cracks were only hair cracks. In the fibre reinforced specimens closely spaced finer cracks were developed and width of such cracks was smaller than those developed in conventional reinforced concrete joint. It was observed that the use of fibre reinforced concrete in the joint core could increase the joint stiffness and minimise damage to the concrete. By comparing the Figure 12 to Figure 14, we can observe that in ordinary specimens wide cracks were developed at the joint and the crack width was more concentrated at the joint. But in fibre reinforced specimens exhibits finer cracks were developed and width of such cracks was smaller than those developed in conventional reinforced concrete joint.
6. Conclusion

From the experimental investigation, it is found that the fibre reinforced beam-column joint with fibre (1.50% of steel fibre) performs better ductility, load carrying capacity, energy dissipation and strength by 10% more than conventional reinforced beam-column joint.

References

[1] Bayasi Z 1989 Development and Mechanical Characterization of Carbon Fibre Reinforced Cement Composites & Mechanical Properties and Structural Applications of Steel Fibre Reinforced Concrete. Dissertation for the Degree of Ph.D., Michigan State University.

[2] Craig R, Mahadev S, Patel C C, Viteri M and Kertesz C 1984 Behaviour of Joints Using Reinforced Fibrous Concrete. Fibre Reinforced Concrete International Symposium SP-81, Am. Concr. Inst. 125-67.

[3] Durrani A J and Wight J K 1984 Behaviour of interior beam-to-column connections under earthquake-type loading. *ACI J. Proc.* 82(3) 343-49.

[4] Gefken P R and Ramey M R 1989 Increased Joint Hoop Spacing in Type 2 Seismic Joints Using Fibre Reinforced Concrete. *ACI Struct. J.* 168-72.

[5] Henager C H 1977 Steel Fibrous, Ductile Concrete Joint for Seismic Resistant Structures. Reinforced Concrete Structures in Seismic Zones. *Am. Concr. Inst.* 53 14371-86.

[6] Johnston C 1994 Fibre Reinforced Concrete: Significance of Tests and Properties of Concrete and Concrete-Making Material. *ASTM STP 169C* 547-561.

[7] Prathibha S and Meher Prasad A 2004 Seismic Vulnerability of existing RC Building In India, *Proc. 13th World Conf. Earthquake Eng.* Vancouver, B.C. Canada 1207.

[8] Sudhir K Jain 1998 Learning from earthquakes. *The Indian Concr. J.* 72(11) 294.

[9] Taylor H P J 1974 The behaviour of in situ beam column joints. *Tech Rep. Cem. Concr. Assoc.* 42 492.

[10] Vollum R L 1997 Design and analysis of reinforced concrete beam column joints. *The Struct. Eng.* 77 23-4.

[11] Prasanna K and Anandh K S 2017 Analysis on Strength of Concrete by Partial Replacement of Riversand with Sawdust and Robosand *ARPN J. Eng. Appl. Sci.* 12 2423-7.

[12] Prasanna K Anandh K S and Ravishankar S 2017 An Experimental Study on Strengthening of Concrete Mixed with Ground Granulated Blast Furnace Slag (GGBS) *ARPN J. Eng. Applied Sci.* 12 2439-44.