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EXPERIMENTAL STUDY ON STEEL FIBER REINFORCED CONCRETE IN BEAM-COLUMN JOINT

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ABRACT

An experiment is reported regarding the effect of using steel fibre reinforced concrete in exterior quarter scale corner beam column joints cast by using M_{20} concrete. The Beam column joint has been analysed using STADD Pro under seismic zone III. All the specimens were designed and casted according to Bureau of Indian Standards, Tested under reversed cyclic loading. All specimens were designed as per IS 456-2000 except the second specimen which was designed and casted as per IS 1893: (Part1) 2002 and detailed as per IS 13920:1993. The remaining three specimens were designed as like first one but using 0.5 % of steel fibers in different face length from beam column joint. The parameters that are to be determined from the experiment include load vs displacement cycle, energy dissipation, Load vs displacement curve, ductility, crack pattern. The beam column joint with Ld -50mm (BCM IV) FRC from face of joint have best performance considering the strength, energy dissipation capacity and ductility factor

Key words: Steel fibre Reinforced concrete, Split Tensile, 0.5 % of Steel fibers, Beam Column Joint.

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1. INTRODUCTION

The recent earthquakes revealed the importance of the design of reinforced concrete (RC) structures with ductile behavior. Ductility can be described as the ability of reinforced concrete cross sections, elements and structures to absorb the large energy released during earthquakes without losing their strength under large amplitude and reversible deformations. Generally, the beam-column joints of a RC frame structure subjected to cyclic loads such as earthquakes experience large internal forces. Conventional concrete loses its tensile resistance after formation of cracks. However, fibre concrete can sustain a portion of its resistance following cracking to resist more cycles of loading. Development of FRC is directly related to a number of recent technological developments. The specific use of these fibers leads to a strengthening of the cement matrix as well as an improvement of ductility behavior of concrete. The improvement of compressive strength is followed by a very strong bond in the interaction zone of aggregate and cement matrix. The weakest components in the high strength concrete structure are the aggregate, while these are the interaction zones in the normal strength concrete. In this article, the experimental study is made by using the steel fibres to increase the ductility in the beam-column joint, which is the most critical region during earthquake.

1.1. Fibre Reinforced Concrete

Fibre reinforced concrete is a concrete mix that contains short discrete fibers that are uniformly distributed and randomly oriented. Fiber material can be steel, cellulose, carbon, polypropylene, glass, nylon, and polyester. The amount of fibers added to a concrete mix is measured as a percentage of the total volume of the composite (concrete and fibers) termed

V_f typically ranges from 0.1 to 3%. Aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d). Fibers with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. The primary role of the fibres in hardened concrete is to modify the cracking mechanism. By modifying the cracking mechanism, the macro cracking becomes micro cracking. The cracks are smaller in width, thus reducing the permeability of concrete and the ultimate cracking strain of the concrete is enhanced. The fibres are capable of carrying a load across the crack. The percentage of Steel fibre used is about 1% is taken constant for all the specimens, the steel fibre length ranges 50 mm and diameter 1mm, aspect ratio ranges about50.

1.2. Beam-Column Joint

The joint is defined as the portion of the column within the depth of the deepest beam that frames into the column1. In a moment resisting frame, three types of joints can be identified viz. interior joint, exterior joint and corner joint. When four beams frame into the vertical faces of a column, the joint is called as an interior joint. When one beam frames into a vertical face of the column and two other beams frame from perpendicular directions into the joint, then the joint is called as an exterior joint. When a beam each frames into two adjacent vertical faces of a column, then the joint is called as a corner joint.

2. DESCRIPTION OF THE FORMWORK

To cast the specimen, four wooden moulds were fabricated. The size of the beam was 500 mm×110 mm × 110 mm and the column size was 600 mm×110 mm ×110 mm.The moulds were nailed to a base plate, in order to keep the alignment accurately.

Figure 1

3. MATERIALS

Water, Fine Aggregate, Coarse, Aggregate, Concrete, Steel Fibres

Table 1

SL. No	Properties	Steel fibre
1	Length	50 mm
2	Diameter	1 mm
3	Aspect ratio	50
4	Modulus of elasticity	210000Mpa
5	Tensile strength	1100Mpa

4. TEST SETUP AND INSTRUMENTATION

All the specimens were tested in a universal testing machine (UTM) of 100 tonnes capacity. The test setup is shown in figure 4.8. The specimen was mounted such that column is in vertical position. A constant axial load of 60 kN which consist of the axial load capacity of the column was applied to the column to keep the column in vertical position and to stimulate column axial load.

A hydraulic jack was used to apply the load at the free end of the beam. To record the load precisely a proving ring was used. The load is applied and measured for every 5mm deflection. The deflection of the beam at the point of loading during test was measured such as 5 mm, 10 mm, 15 mm, 20 mm and 25 mm respectively. Reversal loading is noted for every decrease in deflection.

Figure 2

4.1. Loading History

The exterior beam column joint specimen was subjected to cyclic loading simulating earth quake loads. The displacement sequence consists of 1 mm, 2 mm, 3 mm, 4 mm etc.

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 1 mm deflection and then unloaded. In the second cycle, beam was loaded gradually up to 2 mm and then unloaded and similarly each cycle of load is applied.

5. RESULTS AND DISCUSSION

5.1. General

The beam-column joints with normal reinforcement detailing, seismic reinforcement detailing and with steel fibres (0.5%), were investigated. The parameters that are to be determined from the experiment include load vs displacement cycle, energy dissipation, Load vs displacement curve, ductility, crack pattern.

5.2. Load Vs Displacement Cycle

The load vs displacement cycle is drawn for every specimen, the load is noted for every 1mm displacement, for each cycle of loading. The reversal of loading is noted from the proving ring.

5.3. Load vs Displacement for BCM I

Table 2 Load vs Displacement for BCM I

SPECIMEN ID	BCM I			
Displacement (mm)	LOAD (kN)			
	cycle 1	cycle 2	cycle 3	cycle 4
0	0	0	0	0
1	0.785	0.785	0.782	0.781
2		0.903	1.823	1.825
3			2.85	2.85
4				4.12
3			3.04	2.75
2		1.864	1.475	1.425
1	0.981	0.585	0.525	0.425
0	0	0	0	0
Area of each cycle(kNmm)	0	1.25	3.25	4.25

The Table 2 shows the displacement values in mm and the cyclic load in KN applied on specimen I. The maximum energy absorbing value is 3.5KNmm & total energy absorbing of the specimen is 7.5KNmm

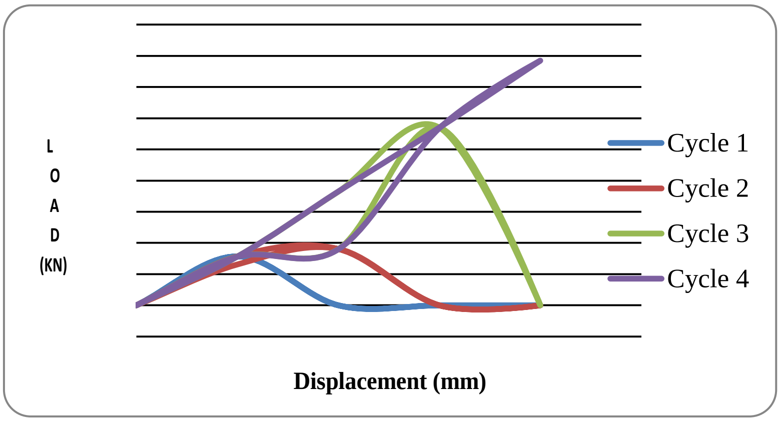

Figure 3 Load vs Displacement cycle for BCM I

5.4. Load vs Displacement for BCM II

Table 3 Load vs Displacement for BCM II

SPECIMEN ID	BCM II			
Displacement (mm)	LOAD (kN)			
	cycle 1	cycle 2	cycle 3	cycle 4
0	0	0	0	0
1	0.981	0.981	0.981	0.981
2		1.864	1.962	2.06
3			3.04	3.04
4				4.12
3			3.04	2.75
2		1.864	1.475	1.425
1	0.981	0.585	0.525	0.425
0	0	0	0	0
Area of each cycle(kNmm)	0	1.25	3.25	4.25

The Table 3 shows the displacement values in mm and her cyclic load in KN applied on specimen II. The maximum energy absorbing value is 4.25KNmm & total energy absorbing of the specimen is 8.75KNmm

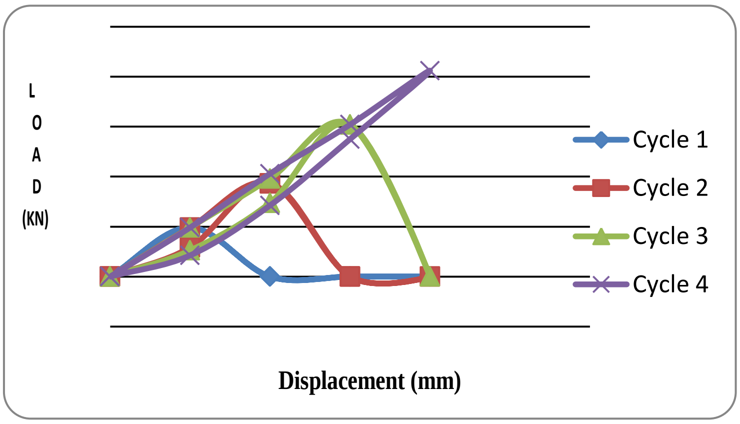

Figure 4 Load vs Displacement cycle for BCM II

5.5. Load vs Displacement for BCM III

The Table 4 shows the displacement values in mm and her cyclic load in KN applied on specimen III. The maximum energy absorbing value is 4.5KNmm & total energy absorbing of the specimen is 8.60KNmm.

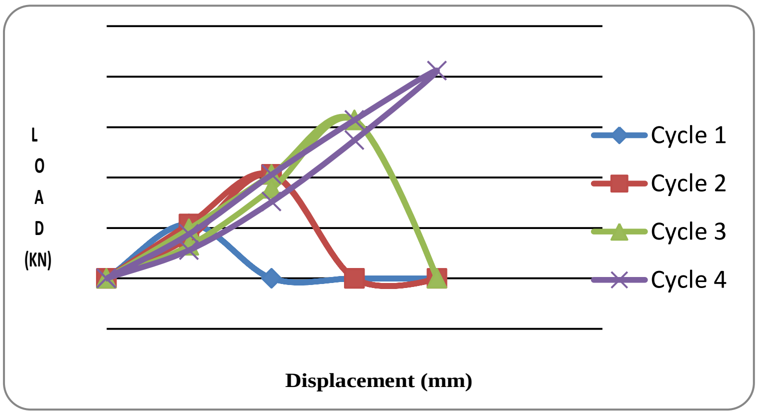

Figure 5 Load vs Displacement cycle for BCM III

Table 4 Load vs Displacement for BCM III

SPECIMEN ID	BCM III			
Displacement (mm)	LOAD (kN)			
	cycle 1	cycle 2	cycle 3	cycle 4
0	0	0	0	0
1	1.08	1.08	0.981	0.88
2		2.06	2.06	2.06
3			3.14	3.14
4				4.12
3			3.14	2.74
2		2.06	1.78	1.52
1	1.08	0.81	0.65	0.561
0	0	0	0	0
Area of each cycle(kNmm)	0	1.35	2.75	4.5

5.6. Load vs Displacement for BCM IV

Table 5 Load vs Displacement for BCM IV

SPECIMEN ID	BCM IV			
Displacement (mm)	LOAD (kN)			
	cycle 1	cycle 2	cycle 3	cycle 4
0	0	0	0	0
0	1.08	1.08	1.08	0.88
2		2.06	2.06	2.52
3			3.04	3.04
4				4.022
3			3.04	2.52
2		2.06	1.962	1.526
1	1.08	1.09	0.88	0.88
0	0	0	0	0
Area of each cycle(kNmm)	0	2.3	3.25	5.25

The Table 5 shows the displacement values in mm and her cyclic load in KN applied on specimen IV. The maximum energy absorbing value is 5.25KNmm & total energy absorbing of the specimen is 10.8KNmm. The energy absobtion capacity for this specimen is maximum compare to other specimens.

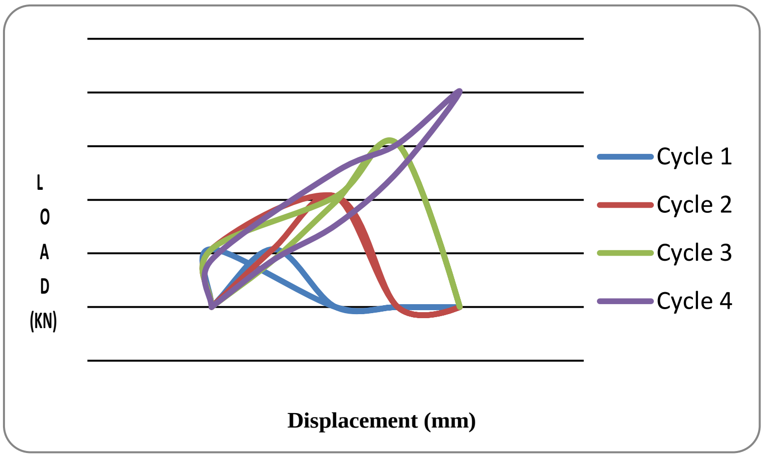

Figure 6 Load vs Displacement cycle for BCM IV

5.7. Load vs Displacement for BCM V

Table 6 Load vs Displacement for BCM V

SPECIMEN ID	BCM V			
Displacement (mm)	LOAD (kN)			
	cycle 1	**cycle 2**	**cycle 3**	**cycle 4**
0	cycle 1	cycle 2	cycle 3	cycle 4
1	0	0	0	0
2	1.275	1.275	1.275	1.08
3		2.256	2.256	2.158
4			3.335	3.335
3				4.12
2			3.335	3.335
1		2.256	1.96	1.62
0	1.275	0.95	0.55	0.55
0	0	0	0	0
Area of each cycle(kNmm)	0	0.9	3.2	4.75

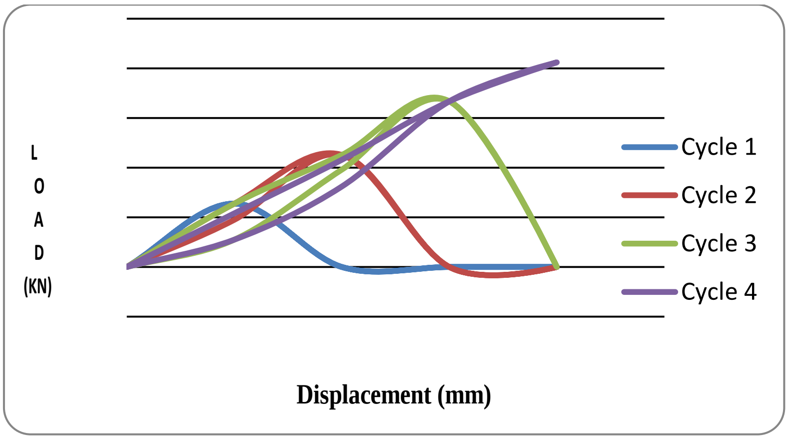

Figure 7 Load vs Displacement cycle for BCM V

The Table 7 shows the displacement values in mm and her cyclic load in KN applied on specimen V. The maximum energy absorbing value is 4.75KNmm & total energy absorbing of the specimen is 8.85 KNmm

Figure 3 to 7 shows the variation of load vs displacement cycle for various beam column joints with various combinations at beam end displacement. The area for each hystersis loop was calculated using this figures. From the figure5 it is inferred that specimen BCM IV has the load carrying capacity (5.25kN) higher than the other beam column joint.

6. ENERGY DISSIPATION VS DEFLECTION

The Table 7 shows the energy dissipation values in KNmm and her deflection in mm for over all specimens.

Table 7 Energy Dissipation vs Deflection

Deflection (mm)	Energy dissipation for Specimens(KNmm)				
	BCM I	BCM II	BCM III	BCM IV	BCM V
1	0	0	0	0	0
2	0.9	1.25	1.35	2.3	0.9
3	3.1	3.25	2.75	3.25	3.2
4	3.5	4.25	4.5	5.25	4.75

7. SPLITE TENSILE STRENGTH

It is very difficult to measure the tensile strength of concrete directly. The split tensile strength is simple to perform and gives more uniform results than other tension tests. Strength determined in the splitting test is believed to be closer to the true tensile strength of concrete (Shetty, 2003). Split tensile strength tests were done on 150 mm dia and 300 mm high cylindrical specimens in compression testing machine of capacity 200 kN. The cylindrical concrete specimens were tested at the age of 28 days for split tensile strength with diametric compression. The ultimate load taken by the specimen was taken for consideration. The split tensile strength of specimens prepared using 20 mm aggregate is summarized in Table 8. The split tensile strength of specimens produced using 20 mm aggregates is graphically shown in Figure 8.

Table 8 Split tensile strength of cube specimens prepared using 20 mm aggregates

Mix ID	Split tensile strength in N/ mm^2
CC 20	3.0
75FA	2.3
50 FA	2.0
25 FA	1.6
00 FA	1.2

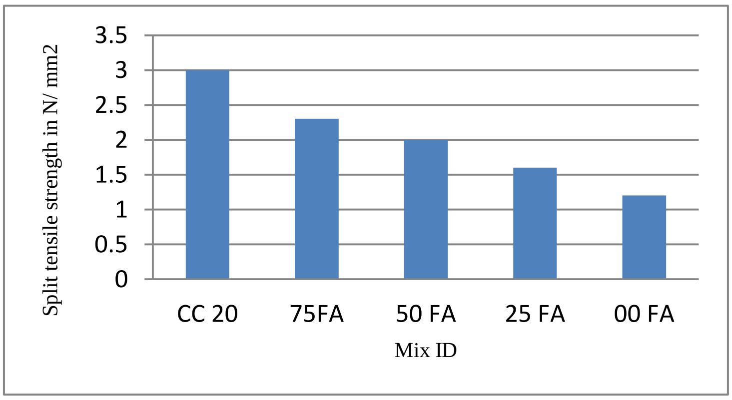

Figure 8 Split tensile strength of all mixes produced using 20 mm aggregates

Split tensile strength of control mix has shown a higher value of 3 N/mm^2. It is found that with the reduction in FA content, the split tensile strength is also reducing. No fines specimen 00 FA has produced a split tensile strength of 1.2 N/mm^2. From this it is understood that 40 % of split tensile strength of control concrete can be attained at no fines concrete when 20 mm aggregates are used as CA. The split tensile strength of specimens prepared using 10 mm aggregate is summarized in Table 8. The split tensile strength of specimens produced using 10 mm aggregates is graphically shown in Figure 9.

Table 9 Split tensile strength of cube specimens prepared using 10 mm aggregates

Mix ID	Split tensile strength in N/ mm^2
CC 10	2.8
75FA	1.8
50 FA	1.5
25 FA	1.4
00 FA	0.9

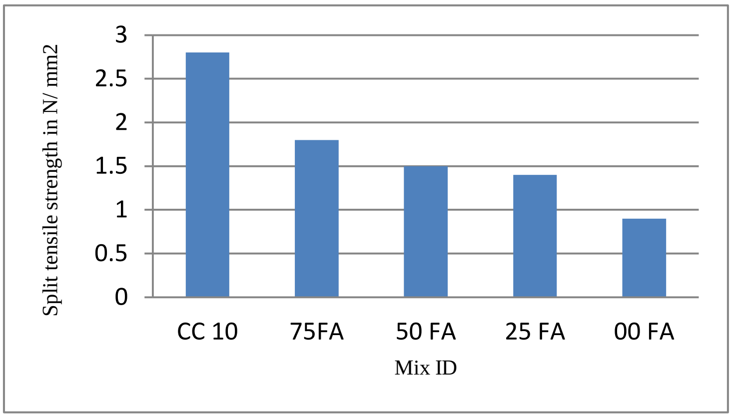

Figure 9 Split tensile strength of all mixes produced using 10 mm aggregates

Split tensile strength of control mix has shown a higher value of 2.8 N/mm^2. It is also found that with the reduction in FA content, the split tensile strength is also reducing. No fines specimen 00 FA has produced a split tensile strength of 0.9 N/mm^2. From this it is understood that 32 % of split tensile strength of control concrete can be attained at no fines concrete when 10 mm aggregates are used as CA.

8. CONCLUSIONS

The following are the major conclusion that is drawn from the present study:

- In this work compressive strength of porous concrete is less than the ordinary concrete.
- It is found that 59.8 % of strength attained in porous concrete after 28 days when 20 mm aggregates are used..
- It is found that 51.2 % of strength attained in porous concrete after 28 days when 10 mm aggregates are used.
- It is found that no-fines concrete produced using 20 mm aggregates have shown more tensile strength than no-fines concrete produced using 10 mm aggregates
- Surface of porous concrete was rough due to the absence of fine aggregate.
- Porous concrete construction is technically variable and feasible.

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