"STUDY ON BEHAVIOUR OF EXTERIOR BEAM-COLUMN JOINT USING M60 CONCRETE AND FIBRE COCKTAIL"

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ABSTRACT: *This experimental study investigates the behaviour of exterior reinforced concrete beam-column joints using special fibre cocktails, (combinations of steel and polypropylene fibres). HPC mix has been designed to obtain a concrete grade of M60 and was designed based on modified ACI 211 method suggested by Shetty. According to BIS five numbers of exterior beam-column joints are modelled and tested under reversed cyclic loading. The results showed that the load carrying capacity for the specimen increase due to combinations of steel fibre and of polypropylene fibre gives the best performance considering the strength, energy dissipation capacity, and ductility factor. Results indicate that the addition of polypropylene fibre to the steel fibre is optimum for a percentage of 0.2, which have more energy absorbing capacity, less joint rotation, more shear strength, more curvature ductility factor and less reinforcement strain.*

Keywords: High strength concrete; hysteresis; cocktail; energy absorption; moment curvature and rotation

1. INTRODUCTION

The structural elements like beam-column are one of the most important parts of existing building that collapse under shear force, which may cause due to earthquakes. The members are of plain concrete, which are weak in tension and have limited ductility and little resistance to cracking. The beam-column joints are moment resisting frame and are subjected to reverse cyclic loading and requires great care in detailing according to the Indian Standard codes. Due to insufficient shear reinforcement and inadequate development length which may cause of joint failure. Steel fibres is one of the materials that is used to enhance the ability of the structures to resist tensile forces such as seismic loads, blast and shock loads, splitting erosion and abrasion, and high temperatures by making the concrete tougher and more ductile. Steel fibre is a ductile material with high tensile strength and has different shapes and styles.

The steel fibre reinforced concrete is normal concrete in which specific amount of steel fibres is present to increase the strength of concrete. The properties of the steel fibre reinforced concrete mainly depend on the concrete mix, steel fibre content, fibre shape and aspect ratio and also the bond characteristics. Due to presence of steel fibres it may increase energy absorbing capacity of the structure that can maintain the integrity of concrete during fracture. This paper presents the results of an experimental program involving cyclic load tests on beam-column joints without transverse reinforcement in which the normal concrete in only the joint area was replaced by HPC. Fibres are expected to improve the properties of concrete both in the unhardened and hardened state. In the unhardened state, fibres increase resistance to plastic shrinkage cracks. In the hardened state, fibres improve the strength (Impact, tensile, flexural and toughness) of concrete, depending on fibres types, shape, size and amount.

Sr. No.	Properties	Steel Fiber (Corrugated)	Polypropylene Fiber
1	Length	30 mm	20 mm
2	Diameter	0.50 mm	0.008
3	Aspect ratio	60	2500

Table No. 1: Details of Fibres

In this study to increase the workability of concrete super plasticizer was added and replacement of cement by silica fume about 10% and 15% by fly ash were considered. The ratio of HPC (M60 grade) mix was (cement-1:0, silica fume-19:0, fly ash-07:1, sand-42:2, C.A-07:0, water-0.35, super plasticizer-0.021). The ratio of HPFRC mix was (1:0.19:0.07:1.31:1.92:0.35: 0.025+1.5%).

2. SPECIMEN MATERIAL AND DESCRIPTION

Cement type Ordinary Portland cement (OPC-53 Grade) and fine sand of locally available was used in this experimental study. Ordinary portable water was used for casting as well as curing of the specimens. The macro corrugated steel fibres and polypropylene fibres (synthetic fibre) were used in this investigation.

Experimental tests were conducted on five beam column joint specimens to study the behaviour of reinforced concrete exterior beam-column joint cast using high performance concrete (HPC). Table 1 shows the details of fibres**.** All specimens had the same reinforcement detailing.

The characteristics of two different concrete mixes used to cast the test specimens are present in Table 2. First mix was used for casting ordinary and seismic specimen and second mix by adding various proportion of polypropylene fibre was used for casting remaining three specimens.

Table No. 2: Characteristics of concrete mixtures (M60).

Material	Unit	Plain concrete	Fiber concrete
Cement	kg/m^3	378	378
Fly Ash	kg/m^3	88	88
Silica fume	kg/m^3	36	36
Fine aggregate	kg/m^3	656	608
Coarse aggregate	kg/m^3	962	891
Water binder ratio	kg/m^3	209	207
Super plasticizer	Lit/m^3	10	11.75
Steel fiber (1.5%)	kg/m^3	-	117.75
Polypropylene fiber (0, 0.2, 0.4%)	kg/m^3	-	(0,1.82,3.64)

For observation four specimens designed as per IS 456:2000 and one specimen designed as per IS 1893 (Part 1): 2002 and detailed as per IS 13920-1993. Table 3 shows the cube and cylinder compressive strength of different combinations of mixtures. In figure 1 the seismic detailing of the above four beam-column joint are shown. From the total four specimens, three specimens were provided with cocktail fibres as presented in Table 2. The beam-column joint without seismic detailing and cocktail fibre reinforced concrete was used in the joint region shown in figure 2. The mix of M60 concrete was used for casting the beam-column joints. Cocktail fibre combination (steel fibre and polypropylene fibre) consisting of 1.5% of steel fibre and 0 to 0.4% of polypropylene fibre with an increment of 0.2 % were used.

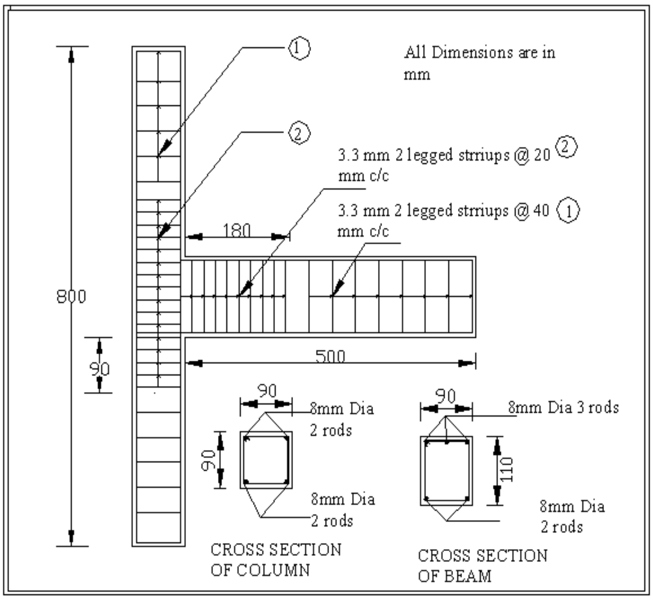

Figure 1: Seismic Joint

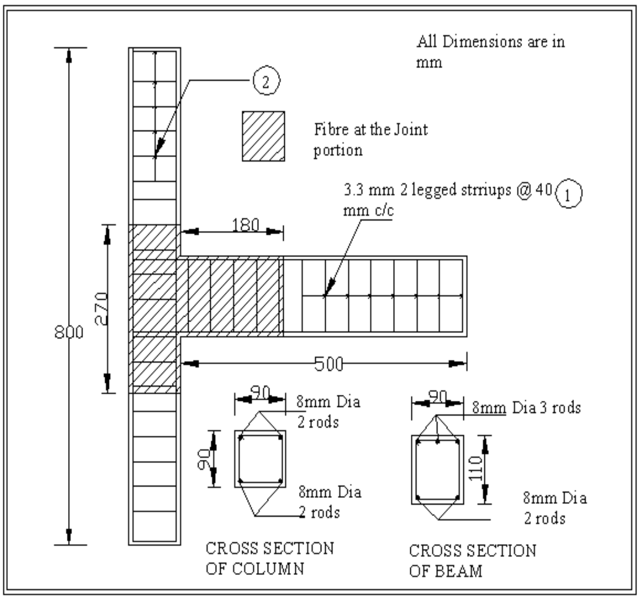

Figure 2: Fiber Joint

3. TEST SETUP

The test setup is shown in figure. The beam column specimen was mounted such that the column is in vertical position and beam is in horizontal position. To apply displacement at the beam end, testing screw jack and hydraulic jack were used. The hydraulic jack was fixed at the strong floor and screw jack was fixed to the loading frame at the top. During the process reversed cyclic load was applied at 50 mm from the free end of the beam. The loading program consisted of a simple history of reversed symmetric displacement of amplitudes 5mm, 10mm, 15mm, 30mm and 45mm. To record the load precisely, proving ring was used and for deflection dial gauges were used. The test was displacement controlled and the specimen was subjected to an increasing reversed cyclic displacement up to failure. Dial gauges were fixed at a distance of D and 2D from the column face on the beam to measure the beam deflections. For measuring the reinforcement strain, Strain gauges were fitted in the beam top and bottom reinforcement. From the above loading history the evaluation of parameters such as load- displacement relation (hysteresis loop), strength, curvature ductility, moment curvature relation, beam and column rotation, shear and energy dissipation etc are observed.

Figure 4: Test set-up

4. RESULTS AND DISCUSSION

Hysteresis loop: The force- displacement hysteresis loops for specimen III F21 is shown in Figure 4

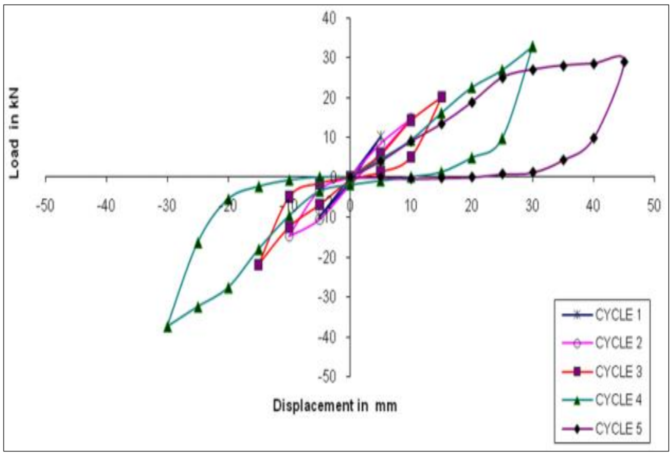

Figure 4: Hysteresis loop for III F 21

Energy dissipation: The area covered by a hysteresis loop at respective cycle represents the energy dissipated by the specimen during the cycle. The Figure 5 shows the energy dissipating capacity of all the specimens. From Table 4 it is observed that the energy dissipation capacity is improved by 178.7% by the addition of 1.5% of steel fibre compared to ordinary specimen (III O1) and by adding cocktail fibre combination of 1.5% steel fibre and 0.2% of polypropylene fibre it is improved by 241%.

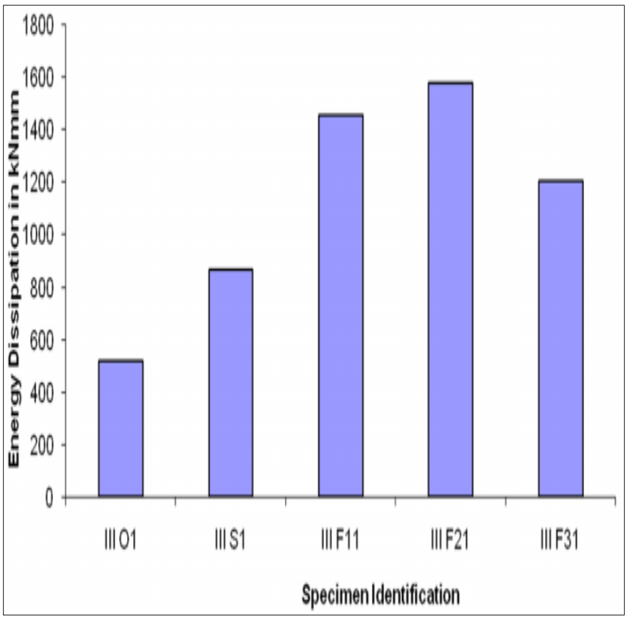

Figure 5: Energy dissipation capacity of all the specimens

Table 4: Ultimate Load, Maximum Deflection at Failure and Energy Dissipation Capacity

Sr. No.	Specimen Id	Ultimate load (Pu) kN		Deflection in (mm)(δ_u)		Energy Dissipation Capacity(e_{cu}) kNmm
		Positive	Negative	Positive	Negative	
1	III O 1	22	21.2	30	30	522
2	III S 1	23.4	26	45	30	866
3	III F 11	30.6	34.4	45	30	1455
4	III F 21	32.7	37.6	45	45	1781
5	III F 31	28.4	30.4	45	30	1207

Table No 5: Details of the Test Specimen and Compressive Strength

Sr. No.	Specimen Id	Detailing Of Lateral Reinforcement	Percentage of fiber		Compressive strength N/mm^2	
			Steel	Polypropylene	Cube	Cylinder
1	III O1	Without seismic detailing	-	-	76.5	61.2
2	III S1	With seismic detailing	-	-	76.5	61.2
3	III F11	Without seismic detailing	1.5	-	84.5	69.3
4	III F 21	Without seismic detailing	1.5	0.2	86.4	71.8
5	III F31	Without seismic detailing	1.5	0.4	82.6	66.9

Joint Shear Stress: Table 6 shows the horizontal and vertical shear stresses developed at the joint due to the ultimate load and the limiting shear stress specified in the joint as per IS codes. The shear stresses induced in the joint (nominal shear capacity) which is calculated at the ultimate load are significantly higher than the limiting values specified in the Joint ACI-ASCE document.

Table No 6: Comparison of Observed Ultimate Shear Capacity with Code Prescribed Limiting Values

Sr. No.	Specimen Id	f'_c N/mm^2	Ultimate load kN	Horizontal shear stress T_{jh}, in 10^{-1} N/mm^2	Vertical Shear stress T_{jv} in 10^{-3} N/mm^2	Limiting shear stress as per 10 ACI = 1.0 $\sqrt{f'_c}$ 10^{-3} N/mm^2
1	III O1	61.2	22	13.2	11.6996	7.82304
2	III S1	61.2	26	15.6	13.8268	7.82304
3	III F11	69.3	34.4	20.64	18.2939	8.32466
4	III F21	71.8	37.6	22.56	19.9957	8.47394
5	III F31	66.9	30.4	18.24	16.1667	8.17924

Moment curvature behaviour: By observing the test result the moment-curvature relationship for all the specimens were calculated. For calculating the curvature ϕ, the strains measured at 15mm below the extreme compression fibre and 15mm above the extreme tension fibre have been used for every loading stage using the relation.

$$\Phi = \frac{e_t + e_b}{(d-dc)}$$

Where,

e_t = strain in the top reinforcement

e_b= strain in the bottom reinforcement

d = effective depth

dc = compressive reinforcement cover

From the experimental values of load and lever arm the values of moment M were calculated. Table 5 shows the moment, curvature ductility at peak load and yield load. These values of M and Φ were used to obtain moment-curvature plots for the joint.

Table No 7: Moment and Curvature Ductility Factor

Sr. No.	Specimen Id	*Φu* (Curvature at peak load) $X_{10}{}^{-2}\frac{1}{m}$	*Φy* (Curvature at yield load) $X_{10}{}^{-2}\frac{1}{m}$	Curvature ductility factor	Moment at peak load kN mm
1	III O1	4.0927	3.0772	1.33	9900
2	III S1	5.4159	3.0772	1.76	11700
3	III F11	9.4373	3.0443	3.1	15480
4	III F 21	10.828	3.0416	3.56	16920
5	III F 31	11.472	3.0510	3.76	13680

5. CONCLUSION

- From the above study it is concluded that the cocktail fibres are effective in resisting deformation at all stages of loading from first crack to failure.
- As in the research study it is observed that the first crack load and ultimate load were found to be increased in the fibre reinforced concrete joints
- Due to adding polypropylene fibre in addition to the steel fibre with the Cocktail combination of 1.5 % steel fibre and 0.2% polypropylyne fibre the ductile behaviour, ultimate strength, joint shear stress, curvature ductility factor and energy dissipation capacity are also increased.
- Hence the cocktail combination of 1.5% of steel fibre and 0.2% of polypropylene fibre is highly recommended in beam column joint subjected to reverse cyclic loading for High Strength Concrete (M60).

6. REFERENCES

[1] Shetty Ms. Concrete Technology Theory and Practice. S. Chand and Company Ltd, New Delhi, 1996

[2] Indian Standard Plain and Reinforced Concrete Code of Practice, IS 456:2000 Bureau of Indian Standards, New Delhi, 2000.

[3] Indian Standard Criteria for Earthquake resistant Design of Structures, Part I General Provisions and Building IS 1893 (Part I) 2002 Bureau of Indian Standards, New Delhi, 2002.

[4] Indian Standard Ductile Detailing of reinforced Concrete Structures subjected to seismic Forces. Code of Practice: IS 13920-1993 (Part 1):2002. Bureau of Indian Standards, New Delhi, 2002.

[5] N. Ganesan, P.V. Indira and Ruby Abraham " Steel Fibre Reinforced High Performance Concrete Beam-Column Joints Subjected To Cyclic Loading" ISET Journal of Earthquake Technology, Technical Note, Vol. 44, No. 3-4, Sept.-Dec. 2007, pp. 445–456

[6] P. Muthupriya, S. C. Boobalan, B. G. Vishnuram Behaviour of fibre-reinforced high-performance concrete in exterior beam-column joint Int J Adv Struct Eng (2014) 6:57 DOI 10.1007/s40091-014-0057-2