Behavior of HFRC Exterior Beam Column Joints under Cyclic loading

C.Geethajali, Dr.P.Muthu Priya, Dr.R.Venkatasubramani

Abstract— **The aim of this experimental investigation is to study the behaviour of Hybrid Fibre Reinforced Concrete in Exterior Beam-Column Joint under Cyclic loading. Concrete mix of M40 grade has designed as per IS10262-2009 with a water cement ratio of 0.4. The fibre combination of steel and Polypropylene at a volume fraction of 0.5% was chosen and six exterior beam column joints were cast and tested. An incremental load of 5kN was applied in the forward cycle to determine the effect of using hybrid fibre reinforced concrete in place of conventional concrete in the joint region. In all exterior beam column joint, the first crack load and ultimate crack load is observed. The behaviour of the exterior beam column is studied by measuring deflection using LVDT. Results showed that the fibres when used in a hybrid form, could result in superior composite performance compared to their individual fibre-reinforced concretes. Concrete containing a fibre combination of S0.75P0.25 can be adjudged as the most appropriate combination to be employed in HFRC to improve strength and ductility.**

***Keywords*: Exterior beam column joint, HFRC, Volume fraction, Load deflection behavior.**

I. INTRODUCTION

Beam column joint is an important component of a reinforced concrete moment resisting frame and should be designed and detailed properly, especially when the frame is subjected to earthquake loading. Failure of beam column joints during earthquake is governed by bond and shear failure mechanism which are brittle in nature. Therefore, a current international code gives high importance to provide adequate anchorage to longitudinal bars and confinement of core concrete in resisting shear.

In RC buildings, portions of columns that are common to beams at their intersections are called beam column joints. Since their constituent materials have limited strengths, the joints have limited force carrying capacity. When forces larger than these are applied during earthquakes, joints are severely damaged. Repairing damaged joints is difficult, and so damage must be avoided. Thus, beam-column joints must be designed to resist earthquake effects. Under earthquake shaking, the beams adjoining a joint are subjected to moments in the same (clockwise or counterclockwise) direction. Under these moments, the top bars in the beam column joint are pulled in one direction and the bottom ones in the opposite direction. These forces are balanced by bond stress developed between concrete and steel in the joint region. If the column is not wide enough or if the strength of concrete in the joint is low, there is insufficient grip of concrete on the steel bars. In such circumstances, the bar slips inside the joint region, and beams lose their capacity to carry load. Further, under the action of the above pull push forces at top and bottom ends, joints undergo geometric distortion; One diagonal length of the joint elongates and the other compresses. If the column cross-sectional size is insufficient, the concrete in the joint develops diagonal cracks. Hence, an attempt has been made to study the behaviour of HFRC beam-column joint under the positive cyclic loading.

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II. EXPERIMENTAL PROGRAM

A. Materials

Cement

Portland-Pozzolana cement of grade 53 was used for casting all the specimens, confirming to IS 1489 (Part 1): 1991.Specific gravity and fineness modulus of cement is 3.15 and 7.5 respectively.

Fine aggregate

Clean and dry river sand available locally was used. Sand passing through IS 4.75 mm sieve was used for casting all the specimens. Specific gravity and fineness modulus is 2.64 and 2.79 respectively.

Coarse aggregate

Coarse aggregate passing through 12.5 mm sieve as given in IS 383 – 1970 was used for all the specimens. Specific gravity and fineness modulus is 2.77 and 5.90 respectively.

Water

Casting and curing of specimens were done using potable water available in the college premises which was free from deleterious materials.

Super Plasticizer

Super plasticizer CONPLAST SP 430, based on Sulfanated naphthalene polymers, complies with IS 9103-1999 and ASTM C-494 was used.

Steel fibers

Continuously crimped Steel fibers with an aspect ratio of 80 were used.

Polypropylene Fibers

Polyolefin fibers with an aspect ratio of 380 were used.

B.Mix Proportion

Mix design has been adopted from IS 10262:2009 to design for M40 grade of concrete. No fibers were added in control

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mix specimen whereas Steel and Polypropylene fibers were

Mix	Cement kg/m^3	FA kg/m^3	CA kg/m^3	Water kg/m^3	SP kg/m^3	Steel Fibre (%)	PP Fibre (%)
BCCM	395	715	1150	158	7.9	-	-
BCS0.5	395	715	1150	158	7.9	0.5	-
BCP0.5	395	715	1150	158	7.9	-	0.5
BCS0.25P0.75	395	715	1150	158	7.9	0.12	0.38
BCS0.5P0.5	395	715	1150	158	7.9	0.25	0.25
BCS0.75P0.25	395	715	1150	158	7.9	0.38	0.12

added to concrete specimen at a volume fraction of 0.5%.

Table 1 Mix proportion for Hybrid concrete

Steel fibers were added by the volume of concrete and polypropylene fibers were added by the weight of cement.

C.**Preliminary Studies**

In the Preliminary studies, the standard sizes of cube (150x150x150mm), cylinder (150mm diameter and 300mm height) and prism (500x100x100mm) were tested as per IS 516-1959. The concluding results were as follows: The cube compressive strength for S0.75P0.25 at 28 days is 61.23 N/mm^2 whereas for control mix it is 43.41 N/mm^2. Split tensile strength at 28 days for S0.75P0.25 is 12.84 N/mm^2 and flexural strength at 28 days is 15.8 N/mm^2.

D.Exterior Beam-Column Joint Specimen Details

All the six exterior beam-column joints had identical beam and column sizes. The column has a cross section of 200 mm x 150 mm with an overall length of 1000 mm and the beam has a cross section of 150 mm x 200 mm with a cantilever portion of length 1000 mm. Figure 1 shows the cross section and reinforcement configuration for the exterior beam-column joint specimens.

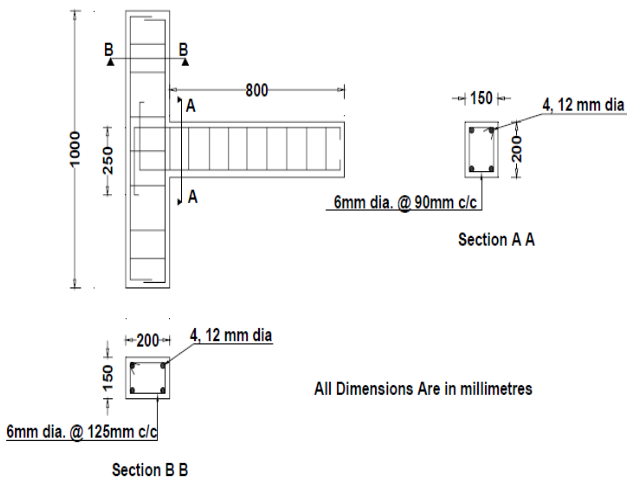

Figure 1 Reinforcement detailing for exterior beam column joint

E. Casting and Testing of Specimens

Plywood moulds were used for casting the specimens. Reinforcement cages were fabricated and placed inside the moulds. Required quantities of cement, sand and coarse aggregate were mixed thoroughly in a drum type mixer machine and 50% of water was added to the dry mix. The remaining 50% water was mixed with the superplasticizer was added along with the steel fibre and polypropylene fibre. The mixes were poured into moulds in layers and the moulds were vibrated for thorough compaction. After 24 hours of casting, specimens were demoulded and cured under wet gunny bags for 28 days.

Specimens were tested in a loading frame of 100 tonne or 1000kN capacity. A constant load of 150kN, which is about 20% of the axial capacity of the column was applied to the column for holding the specimens in position. A hydraulic jack of 50 tonne or 500kN capacity was used to apply load at the beam. A load cell of 50 tonne capacity was used to measure the applied load accurately. Cyclic load with an increment of 5kN was applied to the end of the beam. One number of Linear Variable Differential Transducers (LVDTs) was used to measure the deformations of beam. The schematic diagram of cyclic loading test set-up is shown in Figure 2.

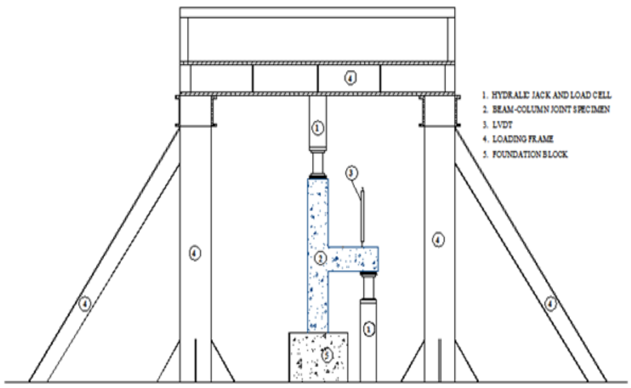

Figure 2 Schematic Diagram of Cyclic loading Test Set-up

III. RESULTS AND DISCUSSION

Figure 3 Experimental set up for beam column joint

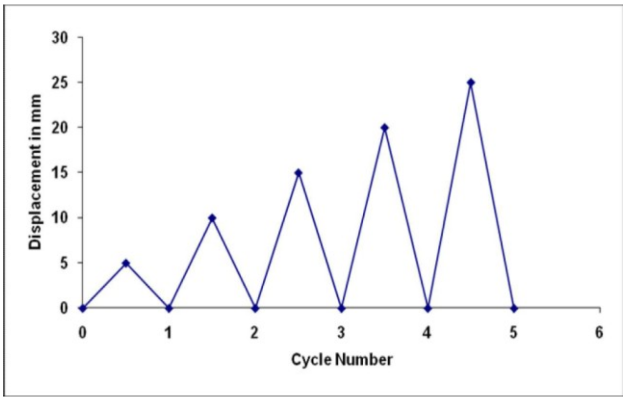

Figure 4 History of cyclic load sequence

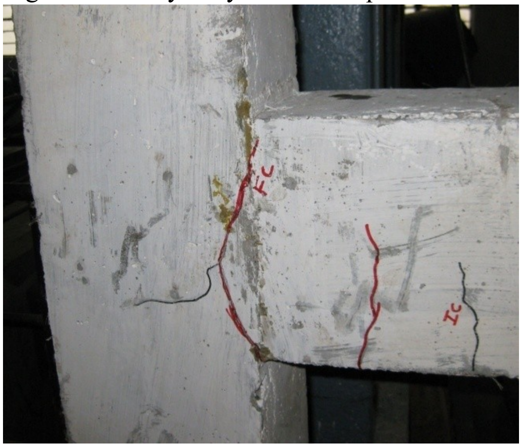
Figure 5(a) Failure in BCP0.5


Figure 5(b) Failure inBCS0.5

Figure 5(c) Failure in BCS0.5P0.5


Figure 5(d) Failure in BCS0.75P0.25

Table 2 Cracking load and Ultimate load of Beam Column Joint under Cyclic loading

MIX	CRACKING LOAD IN kN	ULTIMATE LOAD IN kN
BCCM	5	12
BCS0.5	12	24
BCP0.5	10	20
BCS0.25P0.75	16	26
BCS0.5P0.5	19	28
BCS0.75P0.25	21	33

In all specimens, cracks appeared near the joint after the first crack load. With further increase in loading, the cracks propagated upto the beam and initial cracks started widening. A large number of closely spaced finer cracks appeared in the HFRC beam column joint specimens, and the width of such cracks was smaller than the crack-width in the BCS0.5 and BCP0.5 beam column joint specimens. The cracking load and ultimate load of conventional joint at forward cycle is 5kN and 12 kN respectively. In steel fibrous joint with 0.5% volume fraction the ultimate load is 24 kN The Polypropylene fibrous joint takes an ultimate load of 20 kN. In BCS0.25P0.75the ultimate load at fifth cycle is 26 kN and BCS0.5P0.5 and BCS0.75P0.25 carries 28 kN and 33kN as ultimate load respectively.

IV CONCLUSION

Cracking load increased in hybrid fibre reinforced beam column joint specimens having fibre content of S0.5P0.5 and S0.75P0.25 respectively, when compared to beam column joint containing SFRC specimen. It was found that the addition of fibres bridges the cracking effects and delayed the formation of first crack.

The ultimate load carrying capacity increases by 38% for hybrid BCS0.75P0.25 when compared to steel fibre BCS0.5 beam column join specimen.

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