Characterization of the Beam Column Junction's Performance against Cyclic Load

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Abstract.

A comparison between standard T beam joints and the cyclic stress on Beam Column (BC) joints made out of PP+Steel fiber with varying volume% has been made. The characteristics of energy absorption, hysteresis load vs deflection curve, displacement ductility, and other aspects were also looked at. Investigations into three outside beam-column connections were conducted, and the results were compared to typical concrete instances. According to the testing, ordinary concrete and $(PP_{50\%}+Steel_{50\%})2.0$ both effectively absorbed 514.06 kN-mm and 569.72 kN-mm of energy after four cycles, respectively. Moreover, the $(PP_{75\%}+Steel_{25\%})2.0$ specimen performed at its highest level during the fifth cycle, absorbing 764.18 kN-mm

Keywords: *Displacement ductility, cyclic load, , T beam, and energy absorption of BC joints.*

Introduction:

Ganesan and co. A 2007 scientific study found that SFRHPC could increase the strength, stiffness, and ductility of BC joints. In order to reduce transverse reinforcement congestion in BC joints, it could also be helpful. Investigating the joint's performance focuses on bond and shear transmission for seismic shocks at various joints (S.R. Uma and A. Meher Prasad). Transverse shear reinforcement may only be added up to a certain point before failing to increase shear strength. Shear strength might fail if the combination is too strong at that moment (Rahmani Kadarningsih et al., 2014). An overview of the major cooperative behaviour theories is provided in the paper (Prakash Panjwani, S.K. Dubey 2015).

The current work focuses on studying the response of reinforced concrete (RC) beam-column joints at the corner panel following a ground corner column loss which has been determined through part ductility in particular at its joints. The performance of RC and steel reinforced polymer BC connections has been evaluated for seismic conditions by the authors and results of cyclic testing indicates that companion specimens strengthened with carbon fiber-reinforced polymer (CFRP) systems but did not contain transverse beam stubs (Alessandro De Vita et al., 2017). The testing findings showed that due to their increased load bearing capacity, improved ductility and stiffness response, and less congestion in BC Joints, headed bars may be primarily replaced by traditional bars in earthquake-prone areas (Payal-

Sachdeva et al 2021).In this work, HyFRC materials were created as affordable substitutes for RC knee joint (KJ) constructions in areas with low to moderate seismic risk (S. M. Iqbal et al 2021). According to experimental findings, matrix experiences microfractures, and fiber interception stops the cracks from spreading in the same direction. (2000) (Indira and Ganesan).

Experimental Procedure:

Concrete Mix Ratio :

The mix ratio for the concrete is M40. To get the M40 concrete grade, the IS 10262-2009 standards are followed. The proposed and realized mix proportion is 1:1.94:2.34 with 0.4 as constant water cement ratio.

Table 1 Mix Proportion for M_{40} Grade Concrete

Ingredients of concrete	Weight per Cum	Mix Ratio
Cement in kg/m^3	386	1
Fly ash in kg/m^3	43	0.1
Fine aggregate in kg/m^3	835	1.94
Coarse aggregate in kg/m^3	1024	2.34
Water content in lit/m^3	172	0.4
Super Plasticizer in lit/m^3	4.3	0.01

Test Coupon Preparation:

On the specimen of the T beam, a cyclic load test was conducted. The specimen's strengthening detail is shown in Figure 1. Top and bottom of the beam are reinforced with six 12 mm dia HYSD bars (High Yield Strength Deformed).Stirrup with 2 legs of 6 mm dia HYSD bar implanted at 120 mm centre to centre in the beam is also included. Water-resistant ply wood sheet is also used as a mould. Figure 2 illustrates the PP and steel fiber concentrations. The casting and reinforcement placement in the mould are presented in Figures 3 and 4.

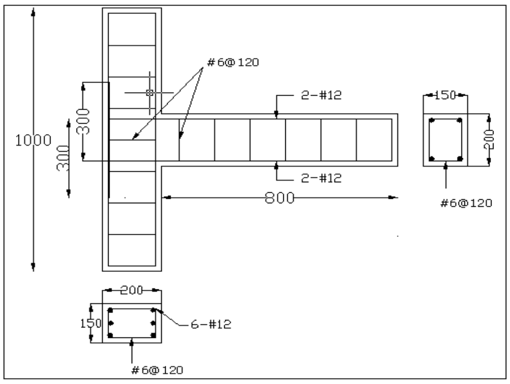

Figure.1 2D Detailing of BC Junction Reinforcement

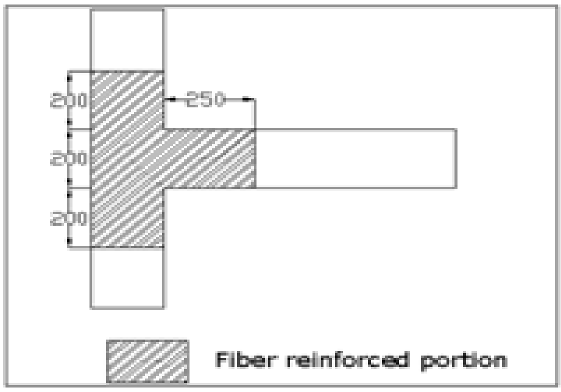

Figure.2 Placement of Fibers in BC Junction

Figure.3 BC Junction - Mould

Figure.4 Reinforcing of the BC Junction

Experimental Arrangement and Procedure:

The studies were carried out at room temperature with a loading frame having a capacity of 100 tonnes. The position shown in figure 5 is maintained while a constant 75KN load is supplied in the axial direction to reduce the column's axial force. By positioning an LVDT in the direction that is counter to the loading direction (the free end of the column), it is possible to track deflection for the applied load. Using a jack with a 4 KN increment rate, the load is delivered at the free end, and proving ring is used for measuring intensity with a minimum count of 0.1 KN. Creation of a load-deflection curve was backed by the experimental findings.

Figure.5: Forward Loading -BC Joint

Results and Discussion:

Load-Deflection Characteristics

The hysteretic Load-Deflection (L-D) behavior of a conventional reinforced concrete BC junction is depicted in Figure 6. Before collapsing, the normal concrete joint was exposed to three complete cyclic loads and just one forward cycle.

The load-deflection behavior of a hysteretic (PP$_{50\%}$+Steel$_{50\%}$) is seen in Figure 7. The beam-column junction is 2.0. Like all other joints, this one could withstand only one forward cycle and three backward cycles before collapsing. The L-D behavior of a hysteretic (PP$_{75\%}$+Steel$_{25\%}$) is depicted in Figure.8. Except for the final cycle, the beam-column junction is Four full cycles of loads and only one forward cycle were applied to the (PP$_{75\%}$+Steel$_{25\%}$)2.0 beam-column connection before the joint gave up. Due to increased fiber bridging and stiffness, this specimen surpasses all other beam-column junctions under cyclic load.

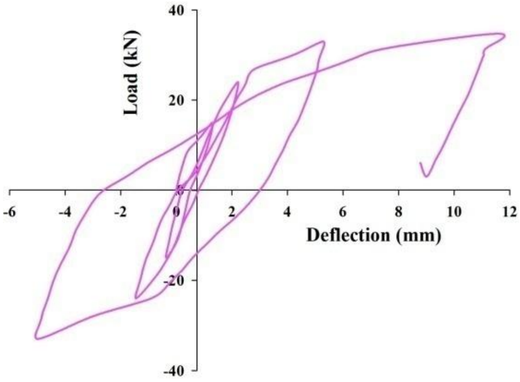

Figure.6 L-D Properties of a Typical RC BC Joint

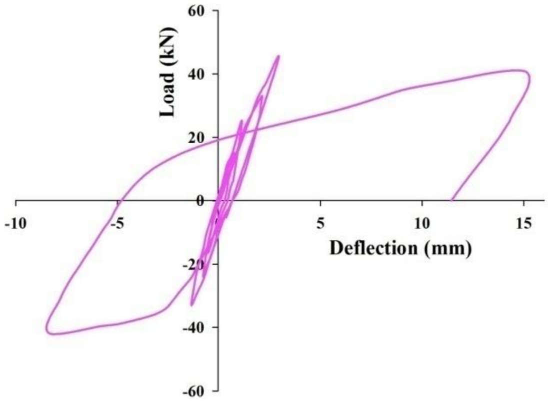

Figure.8 L-D Properties of a (PP75%+Steel25%) 2.0 BC Joint

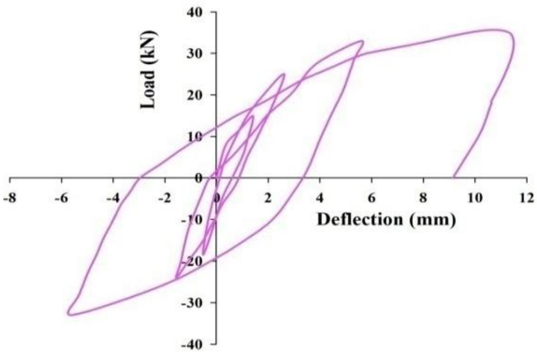

Figure.7 L-D Properties of (PP50%+Steel50%) 2.0 BC Joint

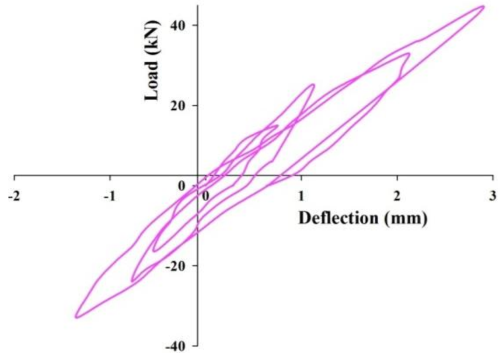

Figure.9 L-D Properties of (PP75%+Steel25%) 2.0 BC Joint without Last Cycle

The failure patterns of conventional concrete, (PP$_{50\%}$+Steel$_{50\%}$)2.0, and (PP$_{75\%}$+Steel$_{25\%}$)2.0 beam-column connections are depicted in Figures 8, 9, and 10. A typical concrete beam-column junction's maximum load-deflection enveloping is shown in Figure 11 from the each cycle hysteresis loop. The joint can withstand a peak load of 34.75 kN, with a corresponding deflection of 11.38. The peak L-D encompassed from each cycle hysteresis loop in the (PP$_{50\%}$+Steel$_{50\%}$)2.0 beam-column joints is depicted in Figures 12 and 13. At maximum load, the (PP$_{75\%}$+Steel$_{25\%}$)2.0 beam-column junction can withstand a cyclic load of 40.7 kN and a displacement of 15.09 mm. ($PP_{50\%}$+$Steel_{50\%}$).Peak load for the 2.0 joint is 38 kN, and peak deflection is 11.59 mm.

Figure.8 Failure Mode - Typical Concrete BC Joint

Figure.9 Failure Mode - (PP50%+Steel50%) 2.0 BC Joint

Figure.10 ($PP_{75\%}$+$Steel_{25\%}$)2.0 BC Joint Failure Mode

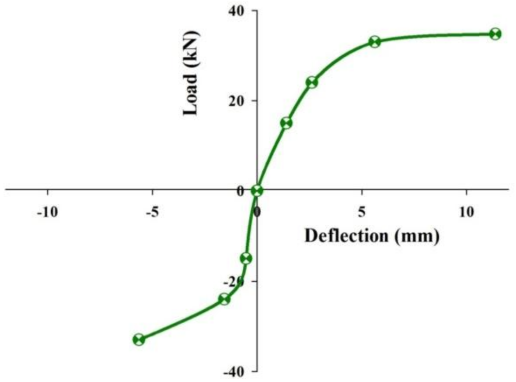

Figure.11 Traditional RC BC Joint L-D Response Envelopes of Hysteresis Curves

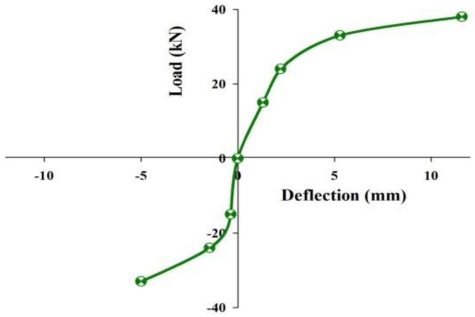

Figure.12 ($PP_{50\%}$+$Steel_{50\%}$) 2.0 BC Joint L-D Response Plot of Hysteresis Curves

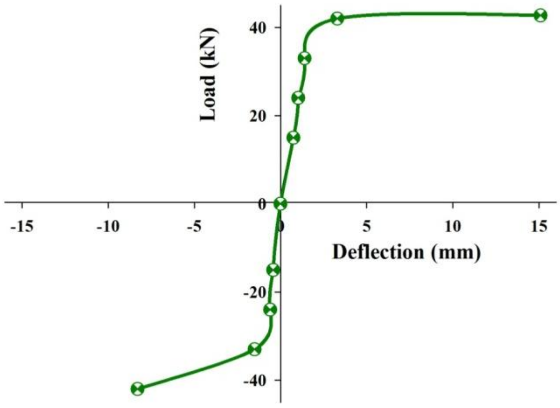

Figure.13 L-D Response Plot of Hysteresis Curves for ($PP_{75\%}$+$Steel_{25\%}$) 2.0 BC Joint

B-C Joints' Absorption of Energy :

Table 2 Combined Absorption of Energy in Constructed Concrete Joints

Cycle	Energy Absorption in Forward Cycle (kN mm)	Energy Absorption in Reverse Cycle (kN mm)	Energy Absorption in each Cycle (kN mm)	Cumulative Energy Absorption (kN mm)
First Cycle	7.5	4.08	11.58	**11.58**
Second Cycle	10.92	16.26	27.18	**38.76**
Third Cycle	76.365	133.44	209.81	**248.57**
Fourth Cycle	265.50	--	265.50	**514.06**

Table 3 Combined Absorption of Energy for (PP$_{50\%}$+Steel$_{50\%}$)$_{2.0}$ **Joint**

Cycle	Energy Absorption in Forward Cycle (kN mm)	Energy Absorption in Reverse Cycle (kN mm)	Energy Absorption in each Cycle (kN mm)	Cumulative Energy Absorption (kN mm)
First Cycle	8.85	4.35	13.20	**13.20**
Second Cycle	17.165	17.1	34.27	**47.47**
Third Cycle	73.16	152.2	225.36	**272.83**
Fourth Cycle	296.89	--	296.89	**569.72**

Table 4 Combined Energy Absorption of (PP$_{75\%}$+Steel$_{25\%}$)$_{2.0}$ Junction

Cycle	Energy Absorption in Forward Cycle (kN mm)	Energy Absorption in Reverse Cycle (kN mm)	Energy Absorption in each Cycle (kN mm)	Cumulative Energy Absorption (kN mm)
First Cycle	3.33	3.36	6.69	**6.69**
Second Cycle	6.69	6.39	13.08	**19.77**
Third Cycle	19.005	15.615	34.62	**54.39**
Fourth Cycle	20.27	220.395	240.66	**295.05**
Fifth Cycle	469.13	--	469.127	**764.18**

The rate of energy absorption for a specimen with a (PP$_{75\%}$+Steel$_{25\%}$)2.0 mix was

6.69 kN mm in cycle 1, 13.08 kN mm in cycle 2, 34.62 kN mm in cycle 3, 240.66 kN mm in cycle 4, and 469.127 kN mm in cycle 5.The B-C connection has absorbed a total of 764.18 kN mm of energy. ($PP_{50\%}$+$Steel_{50\%}$) 2.0 mix absorbs energy at rates of 13.20 kN mm, 34.27 kN mm, 225.36 kN mm, and 296.89 kN mm in the first, second, third, and fourth cycles, respectively. Similar to this, energy absorption rate of regular concrete is 11.58 kN mm in the first cycle, 27.18 kN mm in the second cycle, 209.81 kN mm in the third cycle, and 265.50 kN mm in the fourth cycle. The beam-column junction's energy absorption for each cycle is shown in Figure 14. (PP75%+Steel25%) The 2.0 joint beats the other combinations in terms of load and displacement. This might be because fiber hybridization has an effect on crack arresting and fiber bridging, increasing their effectiveness.

The cumulative energy absorption of conventional concrete, ($PP_{50\%}$+$Steel_{50\%}$)2.0, and ($PP_{75\%}$+$Steel_{25\%}$)2.0 joints is shown in Tables 2-4. Each cycle's energy absorption in the forward and reverse directions of the applied load is described in detail in these tables.

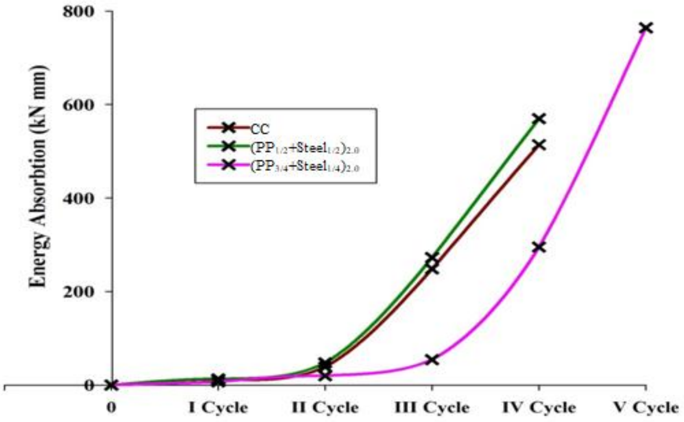

Figure.14 Energy Absorption of all the BC Junctions

Stiffness Degradation of Beam-Column Junctions

The stiffness degradation at B-C connected prepared using ($PP_{75\%}$+$Steel_{25\%}$) 2.0 have shown varying responses in both forward and reverse cycles and it is shown in Table 5.

Table 5 Stiffness Degradation for using ($PP_{75\%}$+$Steel_{25\%}$)2.0

S.No	Cycle No	Stiffness Degradation – Forward Cycle (kN-mm)	Stiffness Degradation – Reverse Cycle (kN-mm)
1	I	20.87	20.1
2	II	20.00	18.29
3	III	15.56	16.5
4	IV	14.33	4.69
5	V	2.42	--

Table 6 displays the stiffness degradation at the B-C connection constructed utilising

($PP_{50\%}$+$Steel_{50\%}$) 2.0, which has demonstrated varied responses in both forward and backward cycles.

Table 6 Stiffness Degradation for using $PP_{50\%}$+$Steel_{50\%}$

S.No	Cycle No	Stiffness Degradation – Forward Cycle (kN-mm)	Stiffness Degradation – Reverse Cycle (kN-mm)
1	I	11.53	17.44
2	II	9.83	10.67
3	III	6.2	4.13
4	IV	2.67	--

Figure 15 depicts the loss of stiffness experienced by all BC connections throughout forward and reverse cycles. Compared to other compositions, the ($PP_{75\%}$+$Steel_{25\%}$)2.0 joint performs better.

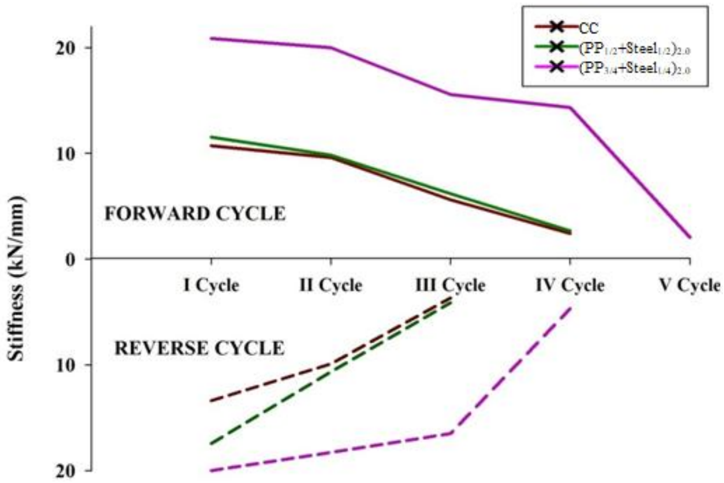

Figure.15 Stiffness Degradation of BC Junctions under Forward and Reverse Cycles

Conclusion

The key discovery from this work relates to flexural testing of BC joints under cyclic stress.

- ($PP_{75\%}$+$Steel_{25\%}$) 2.0 specimens performed the cyclic loading test on the BC juncture. The specimens performed the fifth cycle and then failed.
- The combined energy absorption of the Conventional specimen is 514.06 kN-mm. The value of ($PP_{50\%}$+$Steel_{50\%}$) specimen is 569.72 kN-mm. The value for the ($PP_{75\%}$+$Steel_{25\%}$) 2.0 specimen is 764.18 kN-mm.
- $PP_{75\%}$+$Steel_{25\%}$ 2.0 specimen absorbs 48% more energy than the standard specimen and 34.13% more than the ($PP_{50\%}$+$Steel_{50\%}$) 2.0 specimen.

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