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Study on Exterior Beam Column Joint with Basalt Fibre Under Cyclic Loading

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Abstract: In this investigation, the beam column joint is an important factor for earthquake resistant design of a framed structures, the bending moment and shear force are maximum in the junction area. It is one of the weakest zone. Exterior joint behaves more critically than the interior joint during the occurances of earthquake. This paper present a review of the experimental results associated with behavior of beam column joint under cyclic loading. In experimental investigation was carried out to study the effect of basalt fibre in exterior beam column joint. Addition of basalt fibre to the beam column joint is increases to improve the strength, ductility, hysteresis curve of the joints. In the present work, beam column joints have been caste with plain RC and RC fibres. All the specimens has been detailed by the provisions of IS 13920 incorporation similitude requirements. In high performance of M60 grade of concrete used was designed by using ACI method suggested by Aitcin. Volume fraction of fibres used in this study varies from 0 to 1.25%. The results were compared with various plot like envelope curve, stiffness and ductility. The observed that performance of fibre specimens in term of all the above parameters are better than the conventional beam-column joint.

Keywords: Beam column joint, cyclic loading, basalt fibre, high performance concrete.

I. INTRODUCTION

In RC buildings, portions of column that are common to beams at their intersection 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. In seismic design, reinforced concrete structures must perform satisfactorily under service load conditions. To withstand large lateral loads without serve damage, structures need ductile strength and energy absorption capacity. Moment resisting reinforced concrete frames have gained wide acceptances as an economical structural system that allows energy dissipation without considerable structural damage. In moment – resisting frames, all the lateral force produced by earthquake forces is taken by the frames without help of any shear wall or bearing system. Current design philosophy requires that beam column joints have sufficient capacity to sustain the maximum flexural resistance of all the attached members. The failure of Reinforced concrete frames during earthquakes has demonstrated heavy distress due to shear in the joints that culminated in the collapse of the structures. Shear failure of exterior beam-column joints is identified as the principal cause of collapse of many moment resisting frame buildings during recent earthquakes. S. S. Patil and S. S. Manekari (2013) [1] has been analysis of beam column joint under monotonic loading. They focused on corner and exterior beam column joint and their behaviour , support conditions of beam column joints (i.e) both end hinged and fixed stiffness variation of joints. In this study various parameters are studied for monotonically loaded exterior and corner reinforced concrete beam column joint.

Maruthachalam D and Muthukrishnan V (2012) [2] investigated behavior of reinforced concrete exterior beam column joint a general review. Authors reported that the joint has been comprehensively searched for future research on the behaviour of reinforced concrete beam column joint is discussed briefly. Romanbabu M. Oinam, Choudhury.A.M, And Laskar A (2013) [3] performed experimental study on beam column joint with fibres under cyclic loading. They reported that envelope curve, stiffness, ductility, ultimate load were improve in column strong specimen than the column weak specimen. K.R. Bindhu, P.M. Sukumar and K.P. Jaya (2009) [4] performed of exterior beam column joints under seismic loading. Compare the behaviour of exterior beam column joint sub-assemblages with transverse reinforcements detailed. The authors concluded that the specimens were tested under two different axial loads to evaluate the effect of axial load on the behaviour of joints. N. Ganesan, P.V. Indira and Ruby Abraham (2007) [5] experimentally investigated ten steel fibre specimens of external beam column joint under cyclic loading. They reported that all the specimens undergoes large deformation without developing wider cracks and decrease the rate of stiffness degradation. S. Pampanin, G.M. Calvi and M. Moratti [6] conducted Seismic Behaviour of R.C. Beam-Column Joints Designed for Gravity Loads. They reported experimental tests on six 2/3 scaled beam-column subassemblies. Interior, exterior tee and knee joints, characterized by the use of smooth bars, inadequate detailing of the reinforcement (i.e.total lack of transverse reinforcement in the joint region), deficiencies in the anchorage (hook-ended bars) and the absence of any capacity design principles, were subjected to quasistatic cyclic loading at increasing levels of interstorey drift. The inaccuracy of traditional shear degradation models for exterior joints inpredicting similar damage mechanisms is discussed and possible modifications are suggested. C.Geethajali, Dr.P.Muthu Priya, Dr.R.Venkatasubramani (2014) [7] experimental investigated is to study the behaviour of hybrid fibre reinforced concrete in exterior beam column joint under cyclic loading. 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. Aditya Kumar Tiwary, Ashish Kumar Tiwary, Mani Mohan [8] investigated on strengthening of beam column joint upgraded with CFRP sheets. The authors concluded that they efficiency and effectiveness of carbon fibre reinforced polymer (CFRP) sheets which increasing the shear strength and ductility off seismically deficient beam column joint have been studied. The comparisons results shows that CFRP sheets are very effective in improving shear resistance and deformation capacity of the corner beam column joint and delaying their stiffness degradation. Yamin Patel Elizabeth George Sumant Patel (2013) [9] investigated the behaviour beam column joint made of hybrid reinforced concrete. They reported that the brittle nature of concrete results in sudden unpredictable failure, by using hybrid fibre combination of steel fibre and polypropylene fibre. The hybrid combination of 0.50% steel fibre and 0.50% polypropylene fibre have best performance considering the strength, energydissipation capacity and also beam column joint specimens is tested for shear strength. Hanson NW, Connor HW (1967) [10] has been conducted first experimental study of beam-column joint under simulated earthquake loading in the United States. They were reported regarding moment capacities at first yield of reinforcement, ultimate moment and ductility of the assemblies, maximum beam deflection and anchorage bond stresses of the beam reinforcements.

II.EXPERIMENTAL PROGRAM

2.1 Materials

Cement

Ordinary Portland cement of grade 53 was used for casting all the specimens. Specific gravity and fineness modulus of cement 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 2.54 and 2.64 respectively.

Coarse aggregate

Crushed granite stones passing 12.5 mm and retained on 4.75 mm and having a specific gravity and fineness modulus is 2.75 and 6.89 respectively.

Water

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

Super Plasticizer

AURACAST 405 is a unique combination of new generation super plasticizer based on polycarboxlic either polymer with long lateral chain. It is supplied as a light brown liquid, instantly dispersible in water. This effect is used either to increase the strength or to produce high workability concrete or reduce cement concrete or to retard the setting time of concrete.

Silica fume

Silica fume, also known as micro silica, The main field of application is as pozzolonic material for high performance concrete it is sometimes confused with fumed silica (also known as pyrogenic silica, CAS number 112945-52-5).

Basalt fibre

Basalt fibre is a material made from extremely fine fibres of basalt, which is composed of the minerals plagioclase and olivine. It is similar to fiberglass, having better physic mechanical properties than fiberglass, but being significantly cheaper than carbon fibre. Basalt fiber is made from a single material, crushed basalt, from a carefully chosen quarry source. The fibers typically have a filament diameter of between 9 and 13 µm which is far enough above the respiratory limit of 5 µm to make basalt fibre a suitable replacement for asbestos. They also have a high elastic modulus, resulting in excellent specific strength—three times that of steel.

Product name	**Description**
Material	Chopped basalt fibre
Length	12 mm
Diameter	13 µm
Density	2.66
Specific gravity	2.7
Tensile strength	4500 N/mm^2

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Elastic modulus	90 Gpa
Aspect ratio	92

Table 1 Properties of Basalt Fibre

Figure 1 Chopped Basalt Fibre

2.2 Mix Proportion

HPC mix proportions for M60 grade of concrete were obtained based on the ACI 211 guidelines (ACI,1998) as modified by Aitcin. The details of mix proportions thus obtained are given in table 2. Part of the cement was replaced by micro-fillers such as silica fume. In this study 22% replacement of cement by silica fume. Workability of the mix was kept constant at the compaction factor 0.8.Same mix proportions were maintained for all the mixes. However ,as the basalt fibres were added to theHPC, the workability was found to decrease. Hence in order to maintain uniform workability, dosage of superplastcizer was adjusted in the mix.

Table 2 :HPC Proportions

Material	Unit	Plain Concrete	Fibre Concrete
Cement	kg/m^3	432	432
Silica fume	kg/m^3	50	50
Fine Aggregate(Sand)	kg/m^3	785	785
Coarse Aggregate	kg/m^3	1075	1075
Water cement ratio		150	150
Superplasticizer	Lit/ m^3	7.64	8.75
Basalt fibre (1%)	kg/m^3	-	1.30
Basalt fibre (1.25%)	kg/m^3	-	2.30

2.3 Exterior Beam - Column Joint Specimen Details

All the three exterior beam column joint had identical beam and column sizes. The column has a cross section of 200 mm x 150 mm with an overall length of 1000mm and the beam has a cross section of 150 mm x 200 mm with a cantilever portion of length 600 mm. Figure 2 shows the cross section and reinforcement configuration for the exterior beam-column joint specimens.

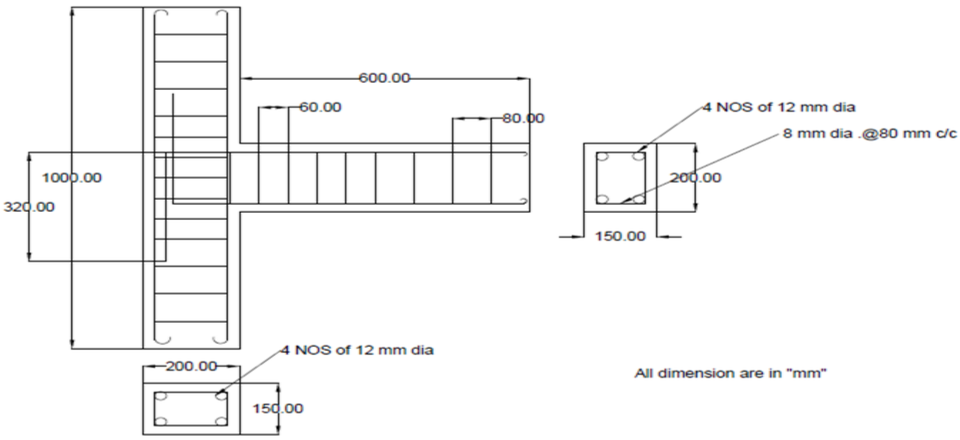

Figure 2 Reinforcement Detailing For Exterior Beam Column Joint

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2.4 Casting and Curing

Plywood moulds were used for casting the specimens. Reinforcement cages were fabricated and placed inside the moulds. Required quantities of cement, fine aggregate 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 the basalt fibres. The mixes were poured into moulds in layers and the moulds were vibrated for through compaction. After 24 hours of casting specimens were demoulded and cured under wet gunny bags for 28 days. After 28 days of curing the specimen was dried in air and white washed.

Figure 3 Reinforcement of Beam Column Joint

2.5 Test setup and instrumentation

The beam column joint specimens are tested under cyclic loading. The load was applied in forward and direction through a hydraulic jack. The loads are applied at equal increments of 1 KN in forward direction till the failure of specimen are applied in forward direction and deflections are measured. Test setup for Beam column joints are show in figure 4.

Figure 4 Test Setup of Beam-Column Joint

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2.6 Experimental Results

Tests are carried out on conventional and basalt fibre reinforced beam column joints and the results are shown in table 3.

Table 3 Test results of beam column joints

Sl.No	Type of Beam Column Joint	Cracking Load in kN	Ultimate Load in kN
1	Conventional beam column joint	10	24
2	Beam column joint with basalt fibre (1%)	12	28
3	Beam column joint with basalt fibre (1.25%)	16	32

2.7 Failure Pattern

The development of cracks in each specimen during testing were carefully observed and recorded by marking the cracks at the peaks of each loading cycle. The cracks of conventional joints increased in width and resulted in spalling of concrete (especially the concrete cover zone) and eventually exposing the steel reinforcing bars. In almost all the specimens tensile cracks were developed at the interface between the column and beam. The specimens failed due to the advancement of crack width at the interface between beam and column. A clear vertical cleavage was formed at the junction of all the specimens.

Figure 5 Failure Pattern of Beam-Column Joint

III. RESULTS AND DISCUSSION

To study the behaviour of beam-column joints under cyclic loading have been enumerated. Here the parameters like load carrying capacity, ductility factor and stiffness are discussed for specimen.

3.1 Load Deflection Behaviour

Load was applied by using hydraulic jack at a distance of 50 mm from the free end of the beam. Totally six cycles were imposed. The load versus deflection diagram for specimen I (conventional beam column joint), specimen II (beam column joint with basalt fibre for 1%), specimens III (beam column joint with basalt fibre for 1.25%).

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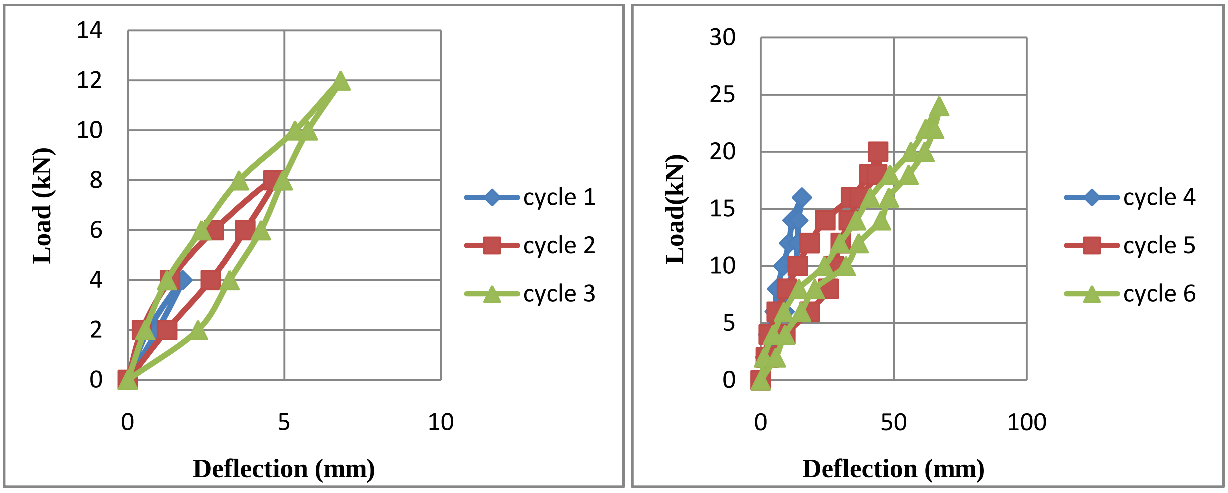

Figure 6 Load Deflection Curve for Specimen I (CC)

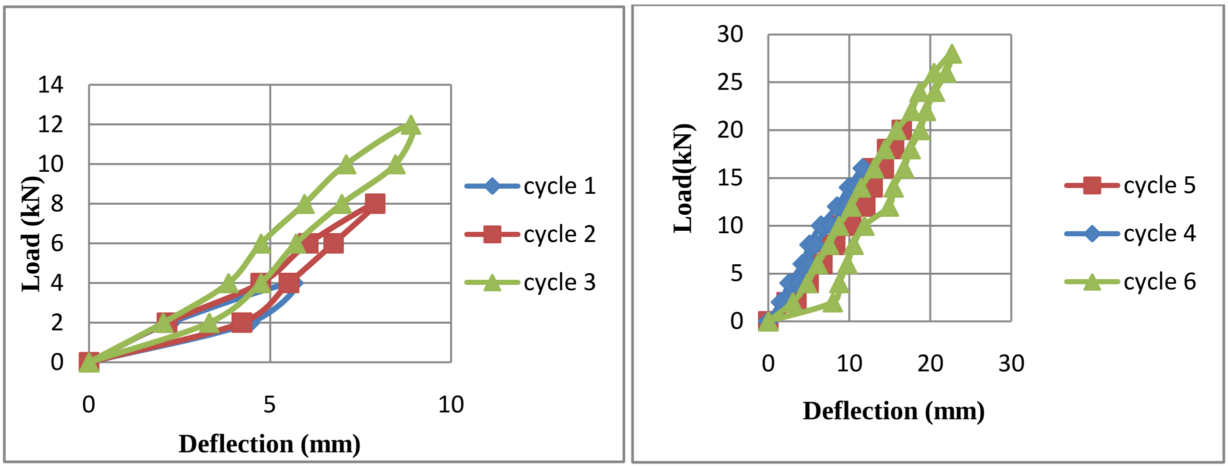

Figure 7 Load Deflection Curve for Specimen II (BF 1%)

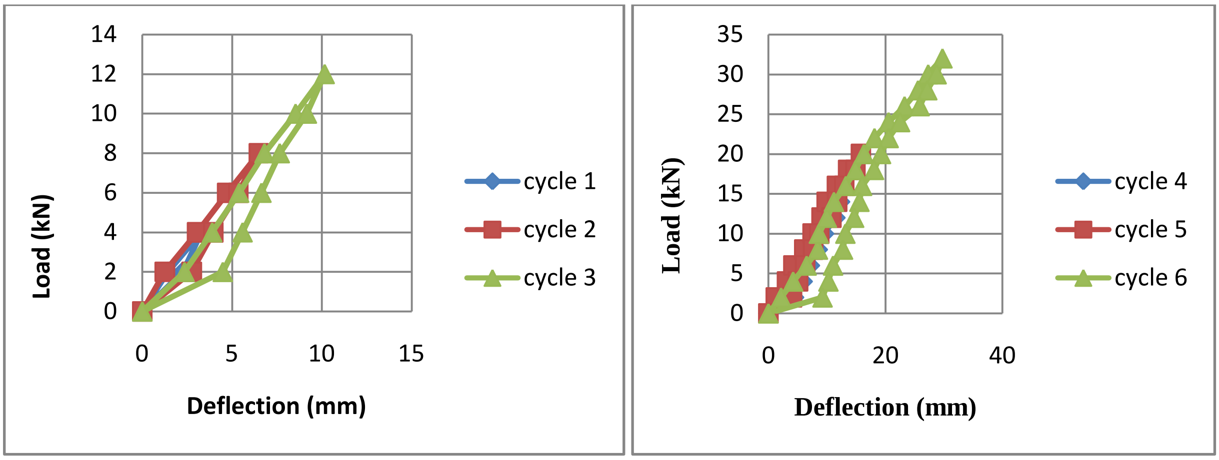

Figure 8 Load Deflection Curve for Specimen III (BF 1.25%)

3.2 Ductility Factor

Ductility of a structure is its ability to undergo deformation beyond the initial yield deformation while still sustaining load. It is obtained by the horizontal distance between the origin and point of intersection of tangents drawn from load deflection curves of the first cycle and last cycle.

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$$\text{Ductility factor} = \frac{\text{Ultimate displacement}}{\text{Yield displacement}}$$

Table 4 Variation of Ductility Factor and Cumulative Ductility Factor for Specimen I(CC)

Cycle No	Ductility Factor	Cumulative Ductility Factor
1	0.15	0.15
2	0.45	0.6
3	0.65	1.25
4	1.45	2.7
5	4.1	6.8
6	6.25	13.05

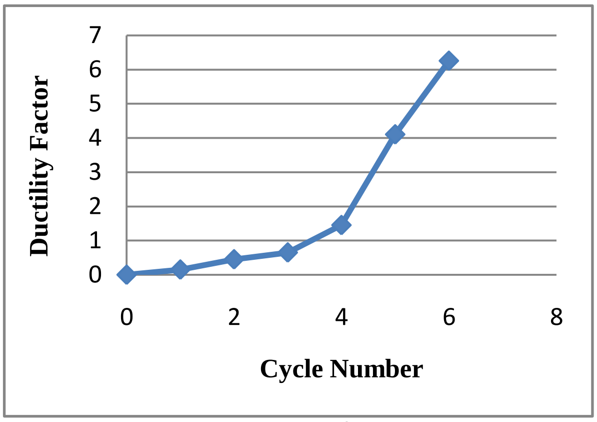

Figure 9 Variation of Ductility Factor for specimen I (CC)

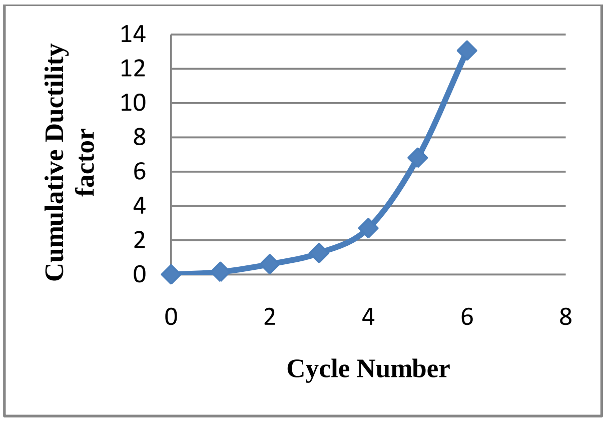

Figure 10 Cumulative Ductility Factor for specimen I(CC)

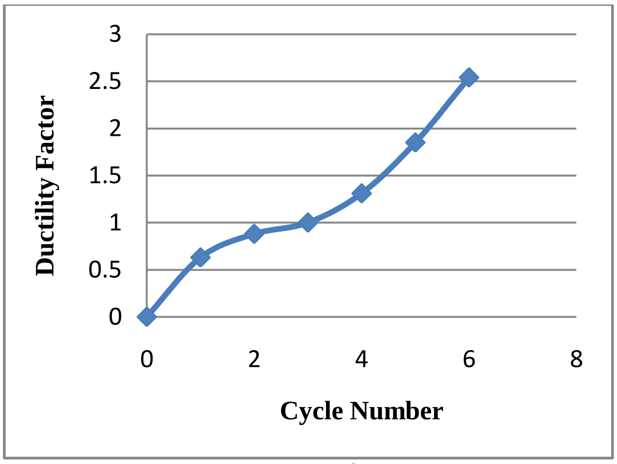

Figure 11 Variation of Ductility Factor for specimen II (BF 1%)

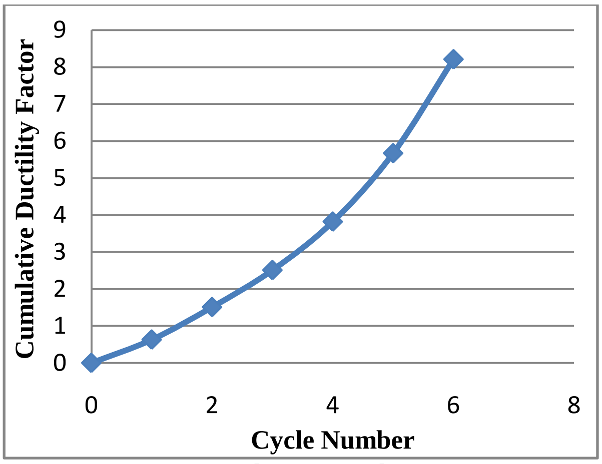

Figure 12 Cumulative Ductility Factor for specimen II (BF 1%)

Table 6 Variation of Ductility Factor and Cumulative Ductility Factor for Specimen III (1.25%)

Cycle No	Ductility Factor	Cumulative Ductility Factor
1	0.26	0.26
2	0.51	0.77
3	0.81	1.58
4	1	2.58
5	1.25	3.83
6	2.35	6.18

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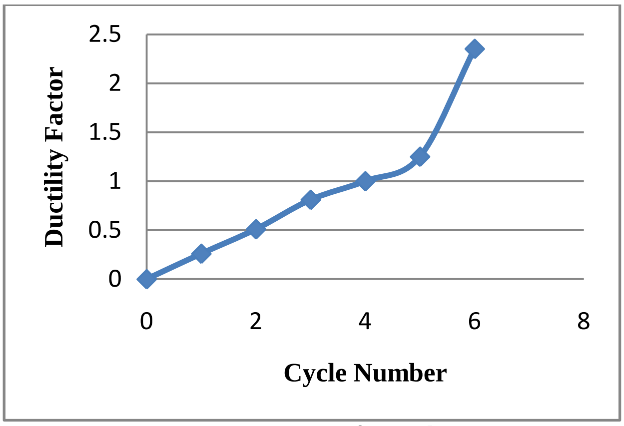

Figure 13 Variation of Ductility Factor for specimen III(BF 1.25%)

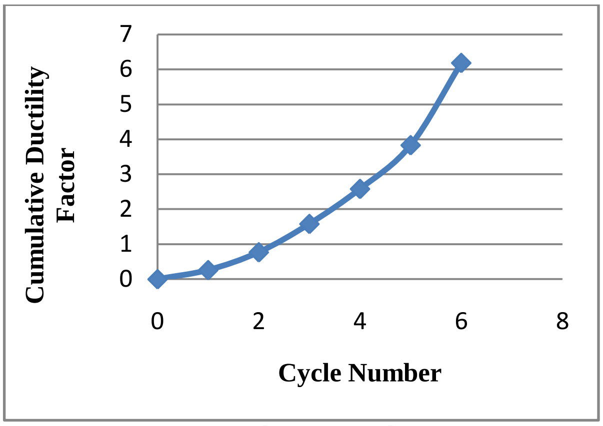

Figure 14 Cumulative Ductility Factor for specimen III (BF 1.25%)

3.3 Stifness

Stiffness is defined as the load required to cause unit deflection of the beam-column joint. The following procedure is used to calculate stiffness of the joint. The recorded loads and corresponding displacements at the end of each half cycle were used to calculate stiffness of each specimen during each cycle of test. The stiffness in each cycle was calculated using a line drawn between the maximum positive displacement point in one half of the cycle and the maximum negative displacement point in the other half of the cycle. Although approximate, the stiffness was used to provide a qualitative measure of the stiffness degradation in the specimens. In general with the increase in the load there is degradation of stiffness occur.

Table 7 Variation of Stiffness Factor

Cycle No	**Stiffness Factor**		
	Specimen I	**Specimen II**	**Specimen III**
1	2.28	0.7	1.21
2	1.72	1.01	1.23
3	1.66	1.35	1.18
4	1.03	1.37	1.27
5	0.45	1.21	1.26
6	0.35	1.23	1.07

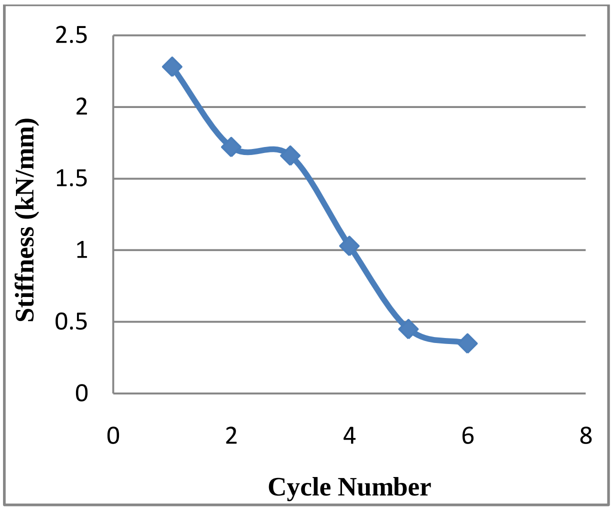

Figure 15 Stiffness of Specimen I (CC)

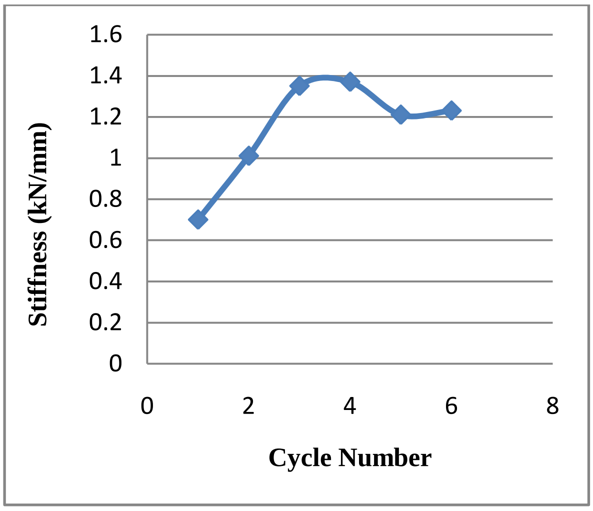

Figure 16 Stiffness of Specimen II BF(1%)

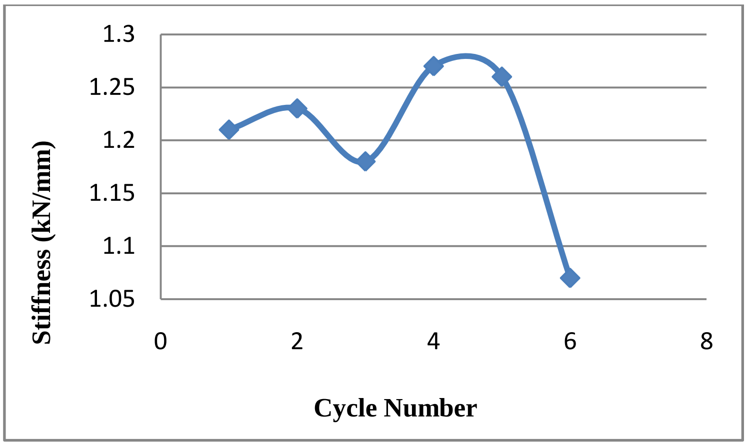

Figure 17 Stiffness of Specimen III BF(1.25%)

IV. CONCLUSION

The structural members or regions still require a significant effort within more comprehensive investigations. The following conclusion are made based on the experimental results and analytical results achieved.

- All the specimens failed due to the development of tensile cracks at the interface between beam and column, and this has ensured that the strong - column weak -beam conditions were satisfied.
- The addition of fibres plays an important role for arresting, delaying and propagating of cracks.
- The beam column joint with basalt fibre with 1% has increased in load carrying capacity by 16.6%.
- The beam column joint with basalt fibre with 1.25% has increased in load carrying capacity by 33.3%.
- Thus the beam column joint with the basalt fibre is safer than the conventional beam column joint which can be recommended for the earthquake resisting structures.
- The cumulative ductility factor of basalt fibre with 1% is about 0.63 times that of conventional beam column joint.
- The cumulative ductility factor of basalt fibre with 1.25 % is about 0.47 times that of conventional beam column joint.

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