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BEHAVIOUR OF FIBRE REINFORCED CONCRETE USING BASALT FIBRE IN BEAM COLUMN JOINT UNDER CYCLIC LOADING

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ABSTRACT

In this study, the effect of fibre reinforced concrete in exterior beam column joint with and without basalt fibre under cyclic loading. And the fibre used in this study is basalt fibre, which is more efficient than other fibres. Mechanical properties like compression, split tension, flexural and impact load test were carried out. Cumulative energy dissipation of all mixes was taken. High performance concrete of M60 grade used. Fibres are used in different percentage (0.75%, 1% and 1.25%) with the volume of concrete. Mechanical properties of the concrete were discussed and the behavior of beam column joint was studied under cyclic loading. To increase the energy absorption and load bearing capacity of the beam column joint ductile detailing is provided. With the load vs deflection, beam column joint curvature is made to find the load bearing capacity. Use fibre to the concrete will reduce the size of crack pattern during failure. The result shows that behavior of beam column joint shows better performance. The studied properties are discussed and the fibre used shows the increase in strength with addition of different percentage of fibre respectively by cyclic loading.

Keywords: basalt fibre, densified silica fumes, beam column joint, energy dissipation capacity, hysteresis curves and stiffness.

INTRODUCTION

In a multi-storied structure, one of critical regions for reinforced concrete building in seismic zones is beam-column joint. It is usually considered as rigid frame. The failure occurs mostly in beam-column joint and the joint is also considered as a crucial structural member [1]. The structural behaviour of the buildings are strongly affected when they are designed only for the gravity loads, which leads to collapse. As observed experimentally the failure region is brittle to the crushing of the concrete. Therefore, fibre presence in the ductile detailed reinforced concrete beam column joints can assist ductile behaviour and act as crack arrestor [4].

Therefore, ductility and energy absorption capacity of the beam column joints are of paramount importance in the seismic resistance of structures which is increased by adding the fibre to the concrete. Hence, adding basalt fibre which is rich in mechanical and ductile property will enhance the energy absorption capacity of the beam column joint.

Basalt is the most common volcanic type rock on the earth. The fibers are obtained from the rock through the melting process. It sounds in mechanical properties as well as toxic and non-combustible.

Therefore the process of basalt fibre in the beam column joint can enhance the structural performance. The results of the beam column joint specimen will strengthen with basalt fiber is more ductile and load carrying capacity is high, which exhibit better structural performance. The combination of fibre with poly propylene was experimentally studied. This gave the 5 percent incremental in the strength of exterior beam column joint [1]. The addition of 1%, 2% and 3% volume fraction of basalt fibre in high performance concrete is investigated to determine the compressive strength, tensile strength and elastic modulus. The basalt fibre up to 2% volume fraction showed significant increase of 10% – 14% in the strength and it reduces 5% of the strength in addition of above 2% of basalt fibre [2]. The effect of basalt fiber as a strengthening fibre for structural members in durability, mechanical properties and flexural strengthening is used in this study. In the weathering test, basalt fiber showed better resistance than glass fibers and in flexural strengthening showed significant increase in the ultimate strength up to 27% in two layers of basalt fiber sheets [5]. The performance of basalt and glass fibers in reinforcing a cementious mortar subjected to impact loading at high strain rate is compared. The experimental investigation shows that the values of compression and flexural test significantly increased the strength when they use basalt fiber than glass fiber under static condition [6]. The tensile, compressive and flexural tests done with the basalt fiber in varying ratios showed good mechanical strength. The 12mm long basalt fiber increases the compressive strength, split tensile strength and flexural strength of concrete and 22mm long basalt fiber increases the toughness [7]. The basalt is the most common volcanic rock type on the earth. The fiber is obtained from the rock through melting process. The ratios of the fiber used in concrete varied from 0.05% - 5%. Basalt fiber has better tensile strength compared to glass fiber [8]. Basalt fibers can withstand high temperature from -260 ^{o}C to + 700 ^{o}C. Due to the good insulation property of fiber it is widely used in the construction industry as an insulation material [9]. Increase in deflection was observed with addition of basalt fiber i.e. 60% deflection increases in beams with basalt fiber reinforced polymer was observed. In composite reinforcement with 35% steel 65% basalt fiber reinforced polymer was effective replacement to make the beam more ductile [10]. The values of the compression and flexural test showed that the strength significantly increased when they use basalt fiber than glass fiber under static condition [11]. The experimental study with the micro basalt fibre shows that the strength was improved but the crack arresting capacity was reduced [13]. The detailed behavior of interior reinforced concrete wide and

convention beam column roof joint under cyclic loading was studied and shows that the wide beam column joint withstands more load than the normal sections to be provided to structure [15].

Cyclic loading to the beam column joint reinforced with the crossed inclined bars had more energy absorption capacity without adding fibre into the concrete [20]. Reinforced beam column joint under loading withstands the seismic load with the proper ductile detailing of the specimen and the reduction in crack patterns [21]. Use basalt fibre to the concrete increased the strength with various percentages. Addition of micro fibre in percentages like 0.5%, 1.5%, 2% and 2.5% resulted better strength with in the 2% of fibre and fibre more than 2% fails in strength [23]. Use Poly carboxylic ether (PCE) based superplasticizer in the study clears that the strength of concrete is increased when the base is added and reduce the water content to the mix [24]. the behavior of castellated beam column joint in cyclic loading shows the much better performance that the normal beam column joint which has more energy absorption capacity [26]. The compressive behavior of basalt fibre to the concrete increases the strength and the basalt carbon hybrid FRP laminates to the specimen bears the strength has loaded bearing capacity. This method of using fibre to the concrete and laminates strengthen the concrete [27].

The research is focused to study the mechanical behaviour of the high performance concrete with a target compressive strength of 60 MPa with various proportions of basalt fibre and also to study the structural behaviour of the beam-column joint under cyclic loading.

MATERIALS REQUIRED

Cement is the binder material which is obtained from the limestone and silica; it has a capability to bind coarse and fine aggregates. In this study ordinary Portland cement of 53grade confirming to IS 12269-1987 was used [17]. Ordinary Portland cement is one of the most widely used Portland cement. Specific gravity tests were conducted in line with IS 4031-1988 with 3.15. Silica fume is also known as micro silica. It is a by-product of the silicon and Ferro-silicon alloy production and consists of round particles with an average diameter of 150nm. It is an ultrafine powder. The main field of application is as pozzalonic material for high performance concrete. The individual particle size of silica fume is extremely small which is roughly about $1/100^{th}$ of individual cement particle. Also, the inclusion of silica fume in concrete possesses greater resistance to chloride ion penetration. Concrete contains silica fumes has high strength and durability [23, 25].

Fine aggregate is one of the most important constituent of a concrete mix. The fine aggregate fills the voids between coarse aggregate. In this project river sand was used. Only that aggregate which passed through 4.75 mm sieve has been taken for mixing with concrete. Specific gravity test and sieve analysis were done on fine aggregate and the results conformed to IS 383:1970 and was found to be Zone II [16].

Coarse aggregate which passed through 12mm and retained on 10mm sieve is used. Specific gravity test was carried out on coarse aggregate and the resultant value was 2.85 which are well within the limits set by IS: 383-1970 specifications [16].

Basalt is an iniquity brown to black volcanic igneous rock originating beneath the soil of kilometers and present on the surface as magma. Its Louis Harold Gray, dark in colour, formed from the solidification of lava. The process involved in production of basalt has the character of extrusion, melt preparation, vulcanized fiber shaping, application of lubricates and finally winding. Method is also known as twist. A fiber is a material made into a long filament with density usually in the order of $300g/cm^2$ of 50cm. The aspect ratio of duration and diameter can be ranging from K to infinity in continuous fiber. It do not pollute air and not to undergo any toxic chemical reaction. The basalt fibre used in the subject is 6mm long and 2.7 of its density.

Super plasticizers are chemical admixtures which are used as high range water reducer in mix proportion. The addition of super plasticizer in mix reduces the W/C ratio without affecting the workability of concrete or mortar and improves the performance of hardening fresh paste. Therefore, polycarboxylic ether base is used in high performance concrete in this study.

EXPERMENTAL INVESTIGATION

In this experimental study, three number of beam column joints were cast and tested with different percentage of basalt fibre. The amount of fibre used for the mix proportions are mentioned in Table-1. The size of the beam column joint is 1 meter column and 0.6 m of beam with cross section of (200×150) mm. The detailed mix proportion for the grade M60 is given in Table-1 as per ACI 211. The mechanical properties of the concrete are discussed. The experimental setup cyclic loading on beam column joint is explained in detail in figure 9. Same setup is used for all 3 specimens to study their strength by loading. Where the column is arrested to be fixed and the beam is subject to loading. Calibrated push-pull jack is used to apply the cyclic loading to the specimen. The addition of three different percentages of fibres is used (0.75%, 1% and 1.25%) and they are mentioned as M1, M2 & M3. M is taken as control mix.

Table-1. Mix proportion.

Mix	Cement kg/m^3	Silica fumes kg/m^3	Fine aggregate kg/m^3	Coarse aggregate kg/m^3	Water l/m^3	Super plasticizer l/m^3	Fibre %
M	478.9	25.2	784.7	1075	150	7.64	0
M1	478.9	25.2	784.7	1075	150	7.64	0.75
M2	478.9	25.2	784.7	1075	150	7.64	1.0
M3	478.9	25.2	784.7	1075	150	7.64	1.25

RESULTS AND DISCUSSIONS

Mechanical properties: The conventional and the basalt fibre reinforced concrete has been tried in three various proportions they are respectively 0.75 percent, 1 percent and 1.25 percent in high strength concrete of grade M60. The compressive strength is done to find the strength of the concrete in compression. The tensile strength test is done to study strength of concrete in tension. The flexural strength is done to study the strength of concrete in bending.

Therefore, the use of basalt fibre in high strength concrete shows the better performance of the concrete. The mechanical properties such compressive strength, tensile strength, Flexural strength and impact load test results are shown in the Figure-1 for both conventional and basalt fibre reinforced concrete. Therefore, the use of basalt fibre in high strength concrete shows the better performance of the concrete. The mechanical properties such compressive strength, tensile strength, Flexural strength and impact load test results are shown in the Figure-1 for both conventional and basalt fibre reinforced concrete.

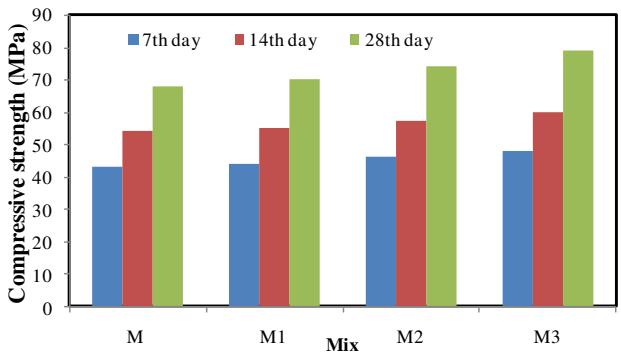

Figure-1. Compressive strength of concrete.

Therefore, the use of basalt fibre in high strength concrete shows the better performance of the concrete. The mechanical properties such compressive strength, tensile strength, Flexural strength and impact load test results are shown in the figure 1 for both conventional and basalt fibre reinforced concrete.

Split tensile strength of all mixes is compared in graph Figure-2, which shows the improved strength of the concrete by adding fibre to the mix. In 28th day, M1 has 3.6% higher than the control mix, M2 had 9.8% higher than the mix M1 and M3 had 18% higher than the mix M2.

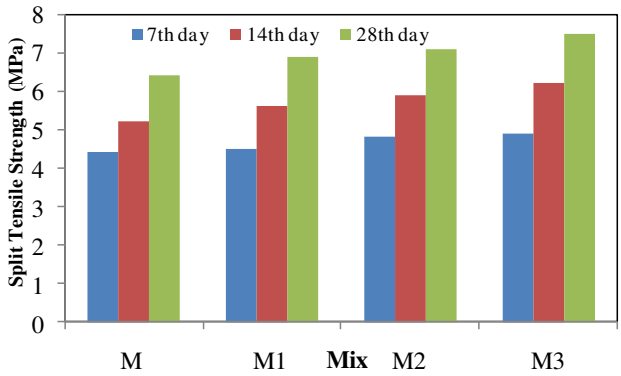

Figure-2. Split tensile strength of concrete.

Flexural strength of all mixes are compared in graph Figure-3, which shows the improved strength of the concrete by adding fibre to the mix. In 28th day, M1 has 4.2% higher than the control mix, M2 had 10.8% higher than the mix M1 and M3 had 17.1% higher than the mix M2.

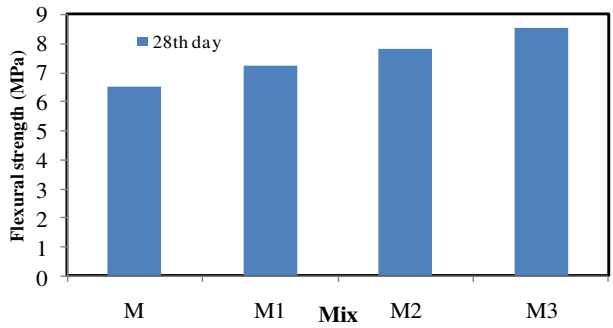

Figure-3. Flexural strength of concrete.

These test result will give the clear strength detail of control mix and fibre mixed concrete. Where all these test results were taken to study the mechanical properties and to compare them with. From the table it shows conventional concrete attained it reach on 7th day, 14th day and maximum at 28th day. For addition of 0.75 percent of basalt fibre to the concrete, shows the comparative increase in the properties and for the addition of 1 percent of basalt fibre shows the good increase in strength while comparing with all other previous mix results.

Impact load test

Drop weight impact load test has a frame 0.6m height and the steel core ball of 3 kg weight is slides up and down the vertical posts upon being attached to a hoist. When the steel ball is released on the cylindrical column. Repetition of the load over the cylinder the initial crack and final crack are noted. The no. of cycle of initial and final crack is increased with respect to the addition of fibre to the concrete as shown in Figure-4

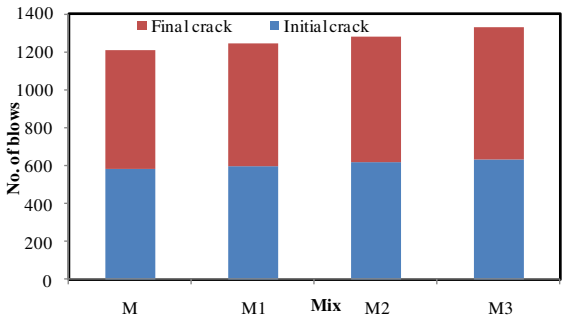

Figure-4. Impact load strength.

Microscopic study

Using field emission scanning electron microscope, it gives finite elemental information about the specimen and in magnifications range of microns, with virtual depth of field. In this the compressed and tensioned concrete samples are scanned to read the particle changes. These particles are studied and analyzed in detail. For the samples of M, M1, M2 and M3 are shown in Figures 1 and 2.

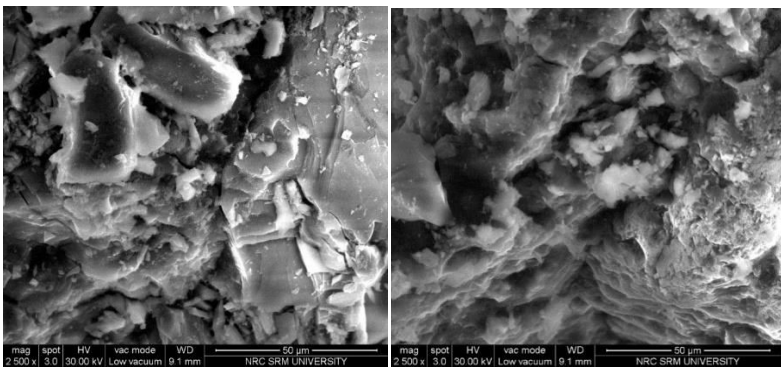

Figure-5. FESEM image of Mix M and M1.

Microscopic investigation on the structure of tested concrete in FESEM method. In which the specimen is subjected to compression, tension, flexural and impact test load. The concrete particles are observed. The modification the structures are also observed. Cracks are observed in dark, silica is observed in white forms and the lumps are found in the voids. In the sample M2 and M3 the appearance on fibre and its modifications are observed.

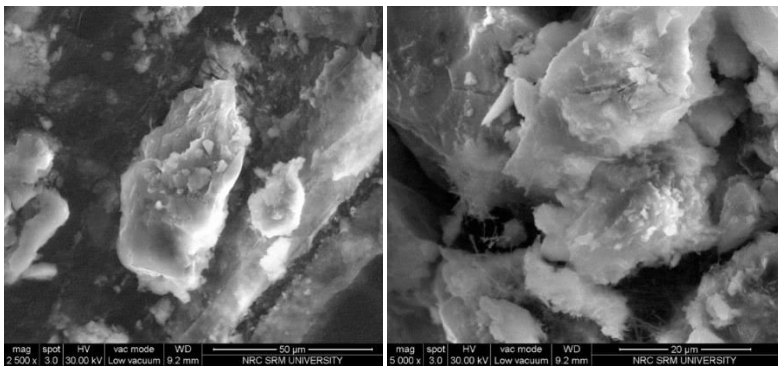

Figure-6. FESEM image of Mix M2 and M3.

ENERGY DISSIPATION FOR THE BEAM COLUMN JOINT

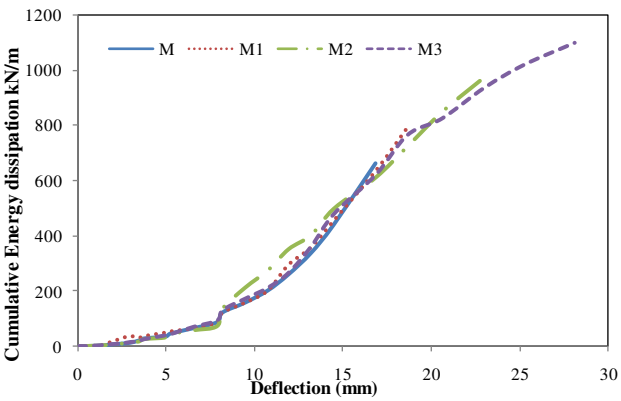

Figure-7. Cumulative energy dissipation of the beam column joint.

The essential parameter of the seismic properties of a structure is capacity of specimen's energy dissipation. The structure which is subjected to seismic action can withstand it by adequate measure of dispersal vitality. This is the region of load deflection circle for each cycle of load. The combined capacities of energy are computed by including the energy which we will get by ascertaining the area of the load deflection graph. From the graph, it shows that the energy dissipation will have corresponding increment too the addition of fibre to the concrete than the control mix. The graph in Figure-7 shows that the energy dissipation of the beam column joint is high in the mix M3. The curve M3 has the more energy dissipation capacity than the other mixes.

STIFFNESS CURVE FOR BEAM COLUMN JOINTS

Stiffness can be estimated by the proportion of load and deflection. The mix M and M1 display the relatively same stiffness and the mix M3 has the higher stiffness of 10% more than conventional concrete. The rate of diminishment of stiffness is relatively same in M and M1.

INSTRUMENTATION AND LOADING ARRANGEMENT

The test set-up is shown in Figure-8. The column of the specimen is placed in vertical position while the beam of the specimen is placed in horizontal position in the set-up. A full cyclic load to beam is applied to the column to represent gravity load. The load to the beam was applied by a jack that was calibrated properly. Fixed supports were used to simulate support condition at both ends of the column.

Figure-8. Beam column joint test setup.

BEAM COLUMN JOINT CURVATURE FOR VARIOUS MIXES

The hysteresis loops presented in Figure 9, 10 and 11 shows that the curvature is the highest in 3rd graph in Figure-11 out of three graphs for the particular deflection. The peak values are noted and the given a curvature with corresponding first cycle to the respective displacement. The curvature of hysteresis loop for the mix M, M1 and M3 are shown in Figure-10, 11 and 12. And Percentage improvement of ultimate load carrying capacity is 15.35%, 19.37% and 24.95% for Mixes respectively. The increased capacity can be studied easily by the graph shown below in Figure-11.

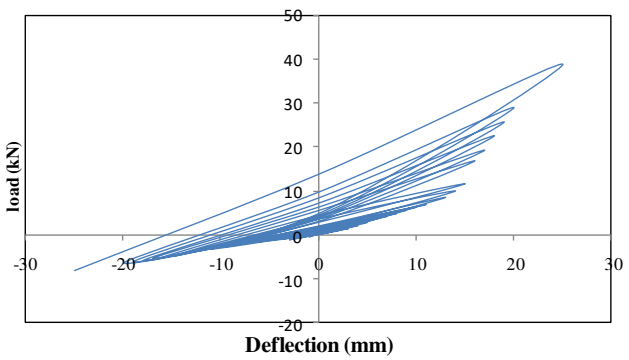

Figure-9. BC joint curvature for mix M.

Graph of mix M2 has more cycles and higher curvature which shows the load bearing capacity and higher deflection shows the higher energy absorption capacity on the beam column joint.

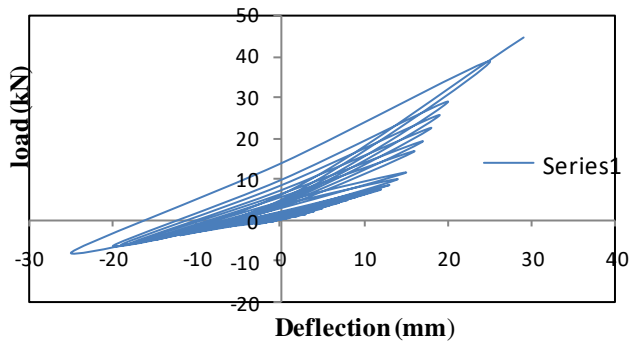

Figure-10. BC joint curvature for mix M1.

Graph of mix M3 has more cycles and higher curvature which shows the load bearing capacity and higher deflection shows the higher energy absorption capacity on the beam column joint as shown in Figure-11.

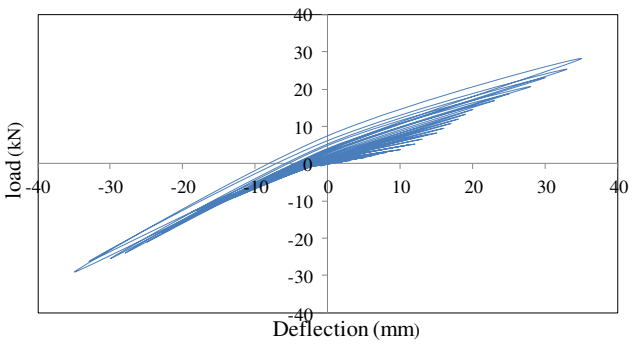

Figure-11. BC joint curvature for mix M3.

On loading there created larger crack in the control mix M and in the fibre reinforced concrete has minor cracks which are arrested mainly due to the addition of fibre to the concrete. The graph above in Figure-11 shows the deflection behavior of the beam column joint on cyclic loading and the initial and final cracks were noted for all the beam column joint while testing are in Table-2.

Table-2. Initial and final crack.

Mix	Initial crack	Final crack & ultimate load
M	5 kN	25 kN
M1	6 kN	29 kN
M3	10 kN	35 kN

This study was compared with the earlier journals with Abbas (2014), in which the study was under strengthen of interior beam column joint was about 19.3 percent anf by strengthen with basalt fibre gives 25 percent and also act as a good crack arrestor. [1] and with Sim C. Park, and D. Moon mechanical properties were compared. Experimental values of the FRC were studied that addition of 2% of basalt fibre to the concrete will fail in strength. So the test in this study is carried within 2% and the strength improvement was studied for each mix. [22]

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CONCLUSIONS

This study helps us to increase the strength of concrete by 25% more than control mix by adding basalt fiber to the concrete in various percentages like 0.75%, 1% and 1.25%. Some of the critical conclusions are listed below:

- From the study, it details that the concrete strength increased by addition of basalt fibre. By adding 0.75% 1 percent and 1.25 percent of fibre to the concrete 2.8 percentage, 8.8 percentage and 16.1 percent of compressive strength is increased when compared to conventional concrete.
- With addition of same percentage of fibre to the concrete 3.6%, 9.8% and 18.6 % of tensile strength is increased in the concrete when compared to conventional concrete.
- In flexure, the strength increased by 4.2%, 10.1% and 17.2% respective to the addition of fibre and addition of fibre 2 percent and more will affect the strength of the concrete.
- Impact strength test of the fibre reinforced concrete shows the better performance than the control mix
- The special confining reinforcement to the specimens as per IS 13920 -1993 had increased in energy absorption capacity with ductile detailing than the specimens with lateral reinforcement as per IS 456-2000
- Stiffness for the beam column joint shows the eventual increase in the addition of fibre to the concrete.
- From the beam column joint curvature graph, it is evident that there is improvement in the load vs

deflection curves thereby increasing the load bearing capacity and energy absorption capacity of the concrete.

- It is concluded that by the addition of basalt fibre into the concrete will enhance the strength and toughness of the concrete.

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