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Seismic Analysis of Basalt Fiber Reinforced Beam Column Joint under Cyclic Loading

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***Abstract:** Beam-column joint assemblage in the RC moment-resisting framed structures is a critical seismic element because its behaviour under severe earthquake motions has a significant effect on failure mode , strength and deformation of the building structures. Basalt Fiber Reinforced Concrete (BFRC) is a concrete with short , discrete lengths of basalt fiber that randomly dispersed. Structures under seismic zone five are often badly damaged or can collapse during earthquakes. The observations from recent earthquakes show that many RC structures have failed in the brittle behaviour of beam-column connections due to the deficiency of seismic details in the joint regions. In this study, RC beam column specimen are modelled in the Ansys with excitation of cyclic loading. Attempts are made to study the performance of the test specimen by studying loop hysteresis, stiffness behaviour and energy dissipation. From the results it has shown that basalt fiber reinforced beam column joint produces less deformation and it act as crack arresters also it produces increase in joint core stiffness compared to conventional concrete beam column joint.*
***Keywords:** Basalt fiber reinforced concrete, ANSYS, hysteresis loop , beam column joint , energy dissipation , stiffness.*

I. INTRODUCTION

Designing beam–column joints is considered to be a complex and challenging task for structural engineers, and careful design of joints in RC frame structures is crucial to the safety of the structure. Although the size of the joint is controlled by the size of the frame members, joints are subjected to a different set of loads from those used in designing beams and columns. It has been identified that the deficiencies of joints are mainly caused due to inadequate design to resist shear forces (horizontal and vertical) and consequently by inadequate transverse and vertical shear reinforcement and of course due to insufficient anchorage capacity in the joint. It was found that many beam-column joints designed with the concept of strong column weak beam concept undergo severe shear force during a seismic event causing joint failure.

A. Objective of the Study

In the current study seismic behaviour of conventional beam column joint and basalt fiber reinforced beam column joint are studied. The basalt fiber reinforced beam column joint generates comparatively small deformation compared to conventional beam column of joint. Hysteresis behaviour , shear and stress behaviour are analysed using ANSYS software.

II. BASALT FIBER REINFORCED CONCRETE

Presence of fiber in concrete improves the physical properties as well it act as crack arresters. As the cement holding the aggregate can crack causing concrete to break concrete is weak in tension. An effective way to improve the tensile strength of concrete and reduce the number of defects is by adding different fraction of fibers. The strength of concrete can be enhanced by fibers enabling the construction to withstand external forces. When plain concrete is compressed, it shatters and fails at the first crack. However, fibers are manufactured specially to prevent the effect of shattering forces by tightly holding concrete together. Basalt fiber reinforced concrete have the potential to improve the mechanical properties of concrete by increasing mainly the concretes tensile strength, fracture toughness and controlled cracking. Basalt fibers are a material made from extremely fine fibers of basalt. The manufacture of basalt fibers require the melting of quarried basalt rock at about 1400 degree Celsius and then it is extruded through small nozzles to produce continuous filaments of fibers. The strength properties of basalt fiber reinforced concrete specimens is influenced by volume and size of fibers.

A. Materials Used

Ordinary Portland Cement (OPC) of 53 grade conforms to IS 12269 was used. Fine aggregate used was Ms and which conforms to Zone 2. 20mm sized coarse aggregate is used to impart strength. Potable water is used. As the basalt fiber I the concrete reduce the workability , sulphonated naphthalene based super plasticizer was also used.

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B. Basalt Fibers

From the literature studies, chopped basalt fiber were preferred at the current work. Basalt is a natural, hard, dense, dark brown to black volcanic igneous rock originating at a depth of hundreds of kilometres beneath the earth and resulting the surface as molten magma. And its grey, dark in colour, formed from the molten lava after solidification. The production of basalt fiber consists of melt preparation, extrusion, fiber formation, application of lubricates and finally winding.. The details of basalt fiber are given in Table I.

TABLE –I

PROPERTIES OF BASALT FIBE

BASALT FIBER	PROPERTIES
Filament diameter	19 micrometer
Fiber type	Chopped basalt fiber
Chopped length	16mm
Aspect ratio	631.57
Density	2670 Kg/m^3

Fig. 1. Chopped basalt fiber

C. Mix Design

The mix design has been adopted from IS 10262:2009 to design for M40 grade of concrete.

TABLE –II

MIX PROPORTION

CEMENT	FA	CA	W/C RATIO	SUPER PLASTICIZER
438 kg/m^3	664 kg/m^3	1172 kg/m^3	197 kg/m^3	4.35 l/m^3
1	1.5	2.7	0.45	0.01

The results obtained after study of mechanical properties of Basalt Fiber Reinforced Concrete (BFRC) with 1% basalt fiber after 28 days are given in TABLE III

TABLE –III

MECHANICAL PROPERTIES OF BFRC CONCRETE

MECHANICAL PROPERTIES	RESULTS
Modulus of Elasticity	81 GPa
Compressive Strength	42.1 N/mm^2
Split Tensile Strength	4.62 N/mm^2
Flexural Strength	4.82 N/mm^2
Poisson’s Ratio	0.33
Density	2222.22 kg/m^3

III. DETAILS OF BEAM COLUMN JOINT

For the design of beam column joint , a ground plus thirteen storey building is analysed in Etabs and beam which shows maximum beanding moment and column attached to it is selected for design. All the design are done as per IS 13920:1993 under seismic zone 5.

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A. *Details of Beam*

The beam consist of two symmetrical spans , calculations need to be performed for one span only. Width and depth of beam are 300mm and 450mm. The section is doubly reinforced section.

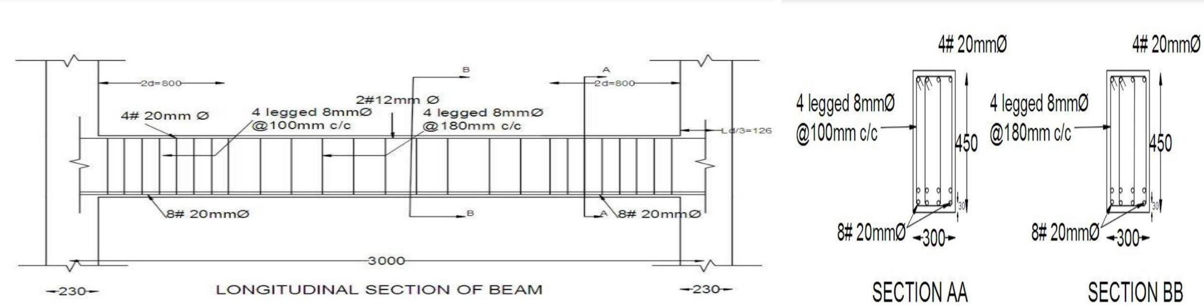

Fig. 2: Longitudinal Section of Beam

The beam consist of 8 number of 20mm diameter at the bottom as 2 layers and 4 numbers of 20 mm diameter at top. Four legged 8mm diameter stirrups are provided as shear reinforcement.

B. *Details of Column*

Interior column element is selected for design. Size of column is 400mmx500mm and effective length of column is 3000mm.Slenderness ratio is obtained as less than 12. Hence it is designed as short column.

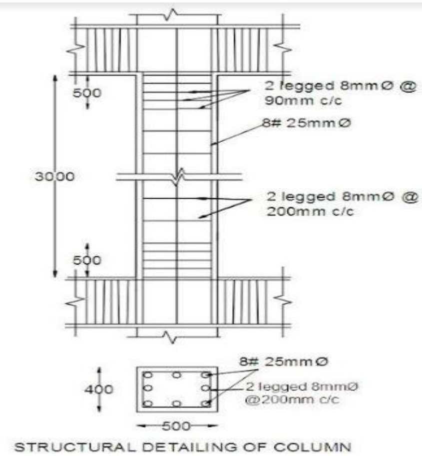

Fig. 3: Structural detailing of Column

It consist of 6 numbers of 25mm diameter bars as main bars and two legged 8mm diameter as lateral ties

C. *Details of Beam Column Joint*

Strong column weak beam concept is adopted. Ductile detailing of column joint is done as per IS 13920:1993. Flexural strength ratios and shear strength are checked and they are safe.

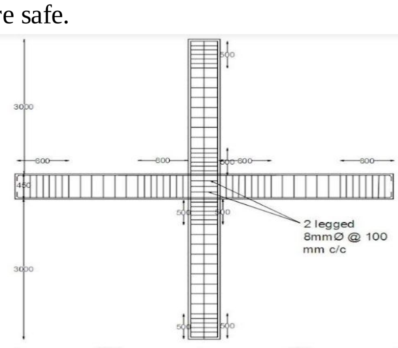

Fig. 4: Detailing of Beam Column Joint

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IV. FINITE ELEMENT ANALYSIS

Finite element analysis was performed using ANSYS program. ANSYS is finite element modelling package which helps in solving even complex problems.

A. Modelling and Meshing

Model of Beam column joint for analysis are created in ANSYS Workbench 17.2. After the modelling , meshing has been done to get accurate results of analysis. It breakups a whole body into pieces , where each piece represents an element. The mesh was setup such that square or rectangular elements are created.

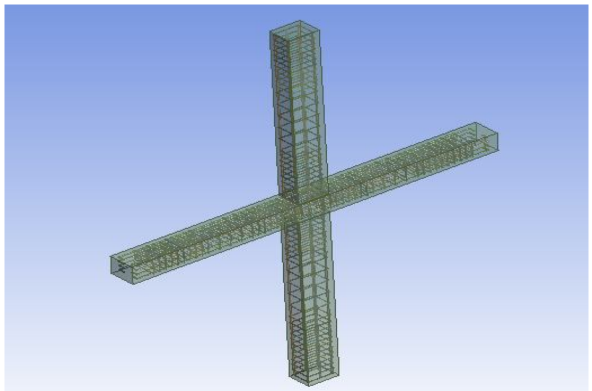

Fig. 5: Geometry of beam column joint

B. Boundary Conditions

The bottom end of column was pinned while both ends of beam were hinged.

C. Analysis Results

After applying loads , total deformation of hysteresis loop was obtained. The deformed shape of beam column joint obtained after analysis are given below. An axial load of 1024 Kn is applied at the top and after that horizontal cyclic load is applied.

V. RESULTS OF FINITE ELEMENT ANALYSIS.

A. Hysteresis behaviour

Fig 6 shows hysteresis loop of horizontal load to displacement for BCJ (Beam Column Joint) specimens. At the early loading stage , the horizontal load ascends linearly with the horizontal displacement. Areas of hysteresis loop are relatively small before yielding of specimen. As the specimen entered yielding stage, inelastic deformations by concrete cracking and reinforcement yield occur in all BCJ specimens.

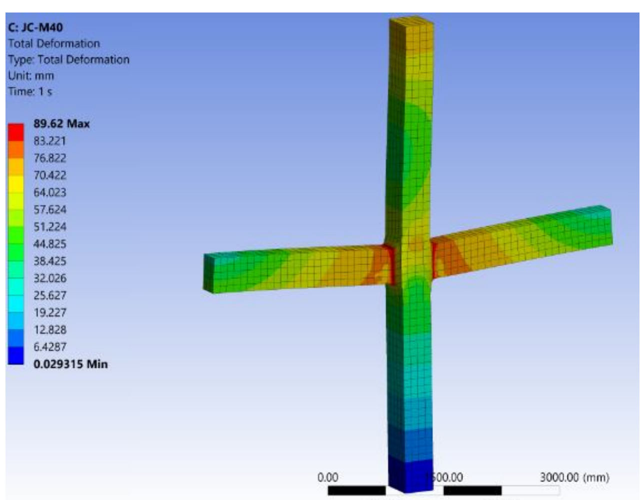

Fig. 6: Total deformation of M40 BCJ

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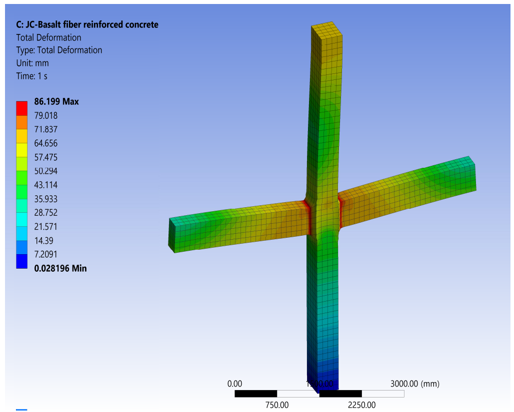

Fig. 7: Geometry of BFRC BCJ (Basalt Fiber Reinforced Beam Column Joint)

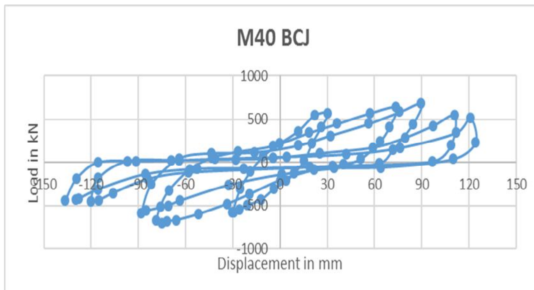

Fig. 8: Hysteresis loop for M40 BCJ

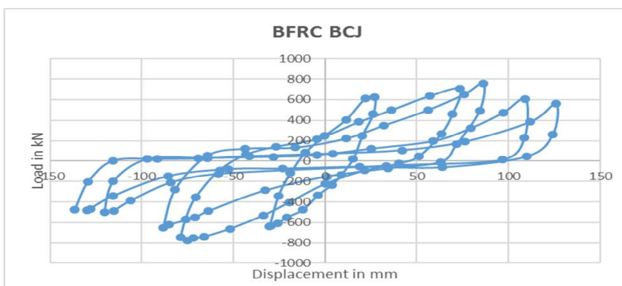

Fig. 9: Hysterisis loop for M40 BCJ

B. Stiffness

Stiffness is calculated as the slope of line connecting positive and negative peak load points in the first cycle under different horizontal displacements. Stiffness value is higher for BFRC BCJ and lesser for M40 BCJ. Fig. 10 shows relationship of stiffness and displacement relation.

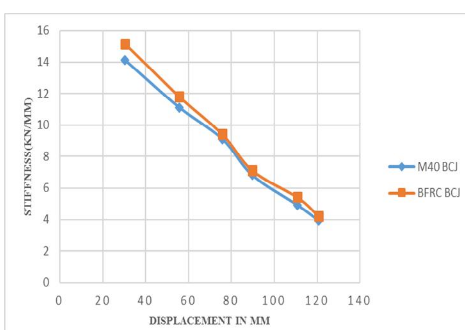

Fig. 10 : Stiffness for BCJ

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C. Energy Dissipation

When the beam column joint is subjected to reverse cyclic loading , such as those experienced during earthquake , some energy is absorbed during each cycle. Energy absorption capacity during various load cycles were calculated as sum of areas under the hysteresis loop. Energy dissipation is more in BFRC BCJ specimens compared to conventional BCJ.

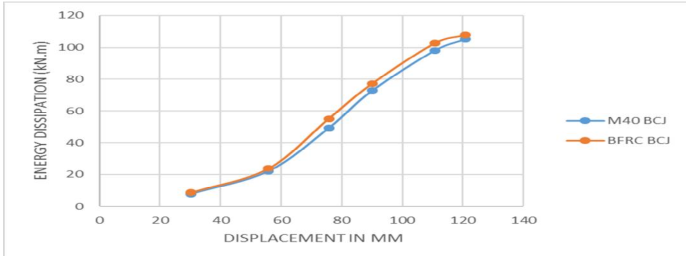

Fig. 11: Energy dissipation for BCJ

VI. CONCLUSIONS

The structural behaviour of RCC interior beam column joint has been studied by analytically using ANSYS. From the analysis result it is concluded that an effective method to improve improve ductility , energy dissipation and stiffness behaviour are addition of suitable fibers. The formation of cracks is more in case of concrete without fiber than the basalt fiber reinforced concrete. Hence it can be concluded that the basalt fiber act as crack arrestors and can prevent sudden failure of the structure.

Initial crack formation is reduced due to this . Hence life of structure will be improved. Deformation of conventional beam column joint is higher than basalt fiber reinforced beam column joint.

VII. ACKNOWLEDGMENT

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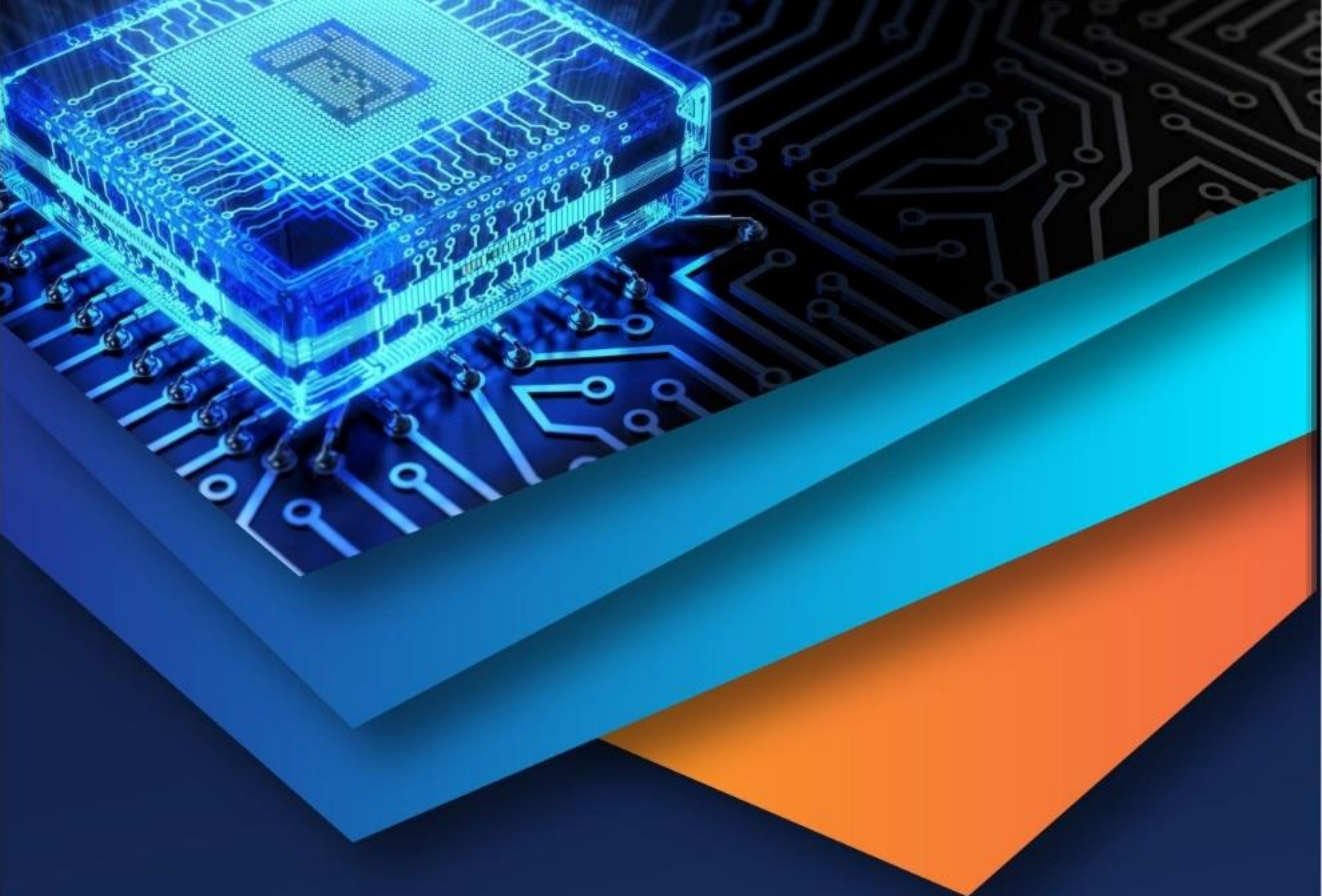

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