ANALYTICAL STUDY ON THE BEHAVIOUR OF BEAM COLUMN JOINT USING BASALT FIBER UNDER CYCLIC LOADING

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ABSTRACT
The beam to column joints are considered as critic regions in reinforced concrete frames. Therefore the beam column joints must be ductile to resist the lateral load. An analytical investigation was carried out to study the effect of basalt fiber in exterior beam column joint. An analytical study is carried out by finite element model using ANSYS. The beam column joint specimens are tested under reverse cyclic loading applied at beam end. The specimens were designed in accordance to the Indian Standard Specification IS 456 (2000). In ANSYS Solid 65 element is used to model the concrete and Beam 188 element is used to model the reinforcement. The basalt fiber is varied at 1.5% volume fraction of the concrete in the specimens. The results of the beam column joint specimens strengthened with basalt fiber exhibit better structural performance.

Key words: Beam column joint, Cyclic loading, Basalt fiber, Hysteresis curve, ANSYS

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1. INTRODUCTION
The beam column joints are critic regions, especially when subjected to seismic loading. To provide adequate ductility of beam column joint, closely placed hoops as transverse reinforcement was recommended. This leads to congestion and difficulty in consolidating concrete in the joints, therefore fiber reinforced concrete are preferred. The beam column joints in the structure are commonly considered as important part in reinforced concrete frames at earthquake prone areas. The moment resistance frame in the beam column joint
controls the transmission of force to the structure. In the design of RC frames, the check for joints is not normal. In recent seismic attacks the joints collapse due to shear failure [1]. The basic concept behind FEM is that a body or structure is divided into smaller elements of finite dimensions called ‘finite elements’. The original structure is considered as an assemblage of elements at a finite number of joints called nodes. The properties of the elements are formulated and combined to obtain the solution for the entire structure [2]. The load carrying capacity of the FRP wrapped RC beam was 60% more than that of the control specimen. The energy absorption capacity of the FRP wrapped RC beam was 30-60% more than the control specimen. In the FRP wrapped beam column joint the failure was noticed only in the beam portion and the column was intact[3]. The GFRP sheets (glass fiber reinforced polymer) and CFRP sheets (carbon fiber reinforced polymer) wrapping for the damaged RC beam column joints proved to be effective by increasing the rigidity and ultimate load carrying capacity, with the decrease in the deflection [4].

The failure of joint region as observed experimentally was brittle. Therefore more brittle behaviour and a lower peak load was predicted. The presence of fibers can ensure ductile behaviour characterized by failure in the beam region with over strength of the column and joint region. Therefore fibers can replace stirrups in the joint region and ensure ductile behaviour of the sub assemblages [5]. In case of steel fiber reinforced high performance concrete and polypropylene fiber reinforced high performance concrete specimens, more number of fine cracks were formed. But the combined effect of steel fibers and polypropylene fibers controlled the cracks at micro and macrolevel. Polypropylene fibers arrest the micro cracks and steel fibers arrest widening of macro cracks as well as increases the energy absorption capacity. Therefore hybrid fiber reinforced high performance concrete beam column joint showed a significant increase in first crack strength, ultimate strength, better ductility and energy dissipation capacity [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, splitting tensile 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 E-glass fiber [8]. Basalt fibers can withstand high temperature from -260°C to +700°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. 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].
2. ANALYTICAL INVESTIGATION

2.1. MATERIALS AND SPECIFICATIONS

<table>
<thead>
<tr>
<th>Specifications of basalt fiber</th>
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<tbody>
<tr>
<td>Length</td>
<td>12mm</td>
</tr>
<tr>
<td>Diameter</td>
<td>13µm</td>
</tr>
<tr>
<td>Density</td>
<td>2.66</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>2.7</td>
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<tr>
<td>Tensile Strength</td>
<td>4500</td>
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<tr>
<td>Elastic Modules</td>
<td>90</td>
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The specimen of beam column joint of M60 grade concrete was created for the cross section 200 X 150 mm, with the beam length of 0.6m and column height of 1m. The beam column joint sizing and reinforcement used in this study are shown in figure 1. For main reinforcement 12mm diameter bars and for stirrups 8mm diameter bars of Fe 415 grade are used at 150mm spacing for column and 120mm spacing for beam. The reinforcement detailing of the two specimens is according to Indian Standard Specification IS 456 (2000). The conventional beam column joint accordance with IS 456 is compared with the basalt fiber reinforced beam column joint accordance with IS 456. The properties of basalt fiber used in this study is mentioned in table 1.

![Figure 1](image1.png)

**Figure 1** Reinforcement details of the specimen

3. MODELLING

In ANSYS Solid 65 element is used to model M60 grade of concrete and Beam 188 element is used to model the reinforcement with 12mm diameter bars for main reinforcement and 8mm diameter bars for stirrups at 150mm spacing for column at 120mm spacing for beam as shown in figure 2 according to IS 456-2000. The top and bottom of the column is constrained in all degrees of freedom in the finite element software as shown in figure 3. In the basalt fiber reinforced beam column joint specimen meshing is done between the fiber and concrete.
4. CYCLIC LOADING

The beam column joint specimens were tested under reverse cyclic loading which is applied vertically in Y-direction at beam end as shown in figure 4. The cyclic loading is the application of repeated stress intensities at a location on structural components. The degradation that occurs at the location is referred as fatigue degradation. The maximum displacement in the assembly and maximum von mises stresses of 0% & 1.5% of the basalt fiber reinforced beam column joint are tested under cyclic loading.
5. LOAD PATTERN

Figure 5 Cyclic load pattern of conventional beam column joint

Figure 6 Cyclic load pattern for 1.5% basalt fiber

Figure 5 & 6 shows the cyclic load pattern of conventional beam column and basalt fiber reinforced beam column joint. The conventional beam column joint takes less cycle of load compared to the basalt fiber reinforced beam column joint. Therefore basalt fiber with 1.5% volume fraction takes more load.
6. RESULTS AND DISCUSSION

6.1. CONVENTIONAL BEAM COLUMN JOINT

Figure 7 Maximum displacement

Figure 8 Maximum von mises stress

Figure 7 & 8 shows the maximum displacement and stress occurred at the joint region of the beam and column. The maximum displacement as 3.08mm and maximum stress as 87.63 Mpa for conventional beam column joint. The failure occurred in the joint region is due to the application of cyclic loading. The von mises is a plasticity theory which is applied to ductile materials to predict the yielding of material under any type of load. The failure occurred in the joint region is due to the application of cyclic loading, which is the repeated stress applied on the same location at the beam end vertically in the Y- direction.

Figure 9 Crack plot for conventional beam column joint
Figure 9 shows the crack plot which was formed for the maximum stress and displacement at the beam column joint for conventional concrete of grade M60 and reinforcement details according to IS 456-2000 under cyclic loading.

6.2. BASALT FIBER REINFORCED BEAM COLUMN JOINT

![Figure 10 Maximum displacement](image1)

Figure 10 Maximum displacement

![Figure 11 Maximum vonmises stress](image2)

Figure 11 Maximum vonmises stress

Figure 10 & 11 shows the maximum displacement and stress occurred at the joint region of the beam and column. The maximum displacement as 884.25mm and maximum stress as 96.28 Mpa for 1.5% volume fraction of basalt fiber reinforced beam column joint. The von mises is a plasticity theory which is applied to ductile materials to predict the yielding of material under any type loading. The failure occurred in the joint region is due to the application of cyclic loading, which is the repeated stress applied on the same location applied at the beam end vertically in the Y-direction.

![Figure 12 Crack plot for 1.5% basalt fiber reinforced beam column joint](image3)

Figure 12 Crack plot for 1.5% basalt fiber reinforced beam column joint
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Figure 12 shows the crack plot which was formed at the beam column joint region for the maximum stress and displacement. The crack was formed at beam column joint for 1.5% volume fraction of basalt fiber reinforced concrete of grade M60 and reinforcement detailing according to IS 456-2000 under cyclic loading.

7. HYSTERESIS BEHAVIOUR

7.1. CONVENTIONAL BEAM COLUMN JOINT

The load vs deflection behaviour of the conventional beam column joint is shown in figure 13. The values are plotted from the analytical investigation of the beam column joint with 0% basalt fiber reinforced beam column joint. Since the cyclic loading is applied at the beam column joint, the stiffness degrades at various cycle of load which is applied continuously. The hysteresis behaviour of the conventional beam column joint shows that the joint is stiffer and less ductile. It fails at 70KN with 3.08 mm deflection.

7.2. BASALT FIBER REINFORCED BEAM COLUMN JOINT

The hysteresis behaviour of beam column joint with 1.5% basalt fiber

Figure 13 Hysteresis behaviour of conventional beam column joint

Figure 14 Hysteresis behaviour of beam column joint with 1.5% basalt fiber
The figure 14 shows the load vs deflection for the 1.5% basalt fiber reinforced beam column joint. The values are plotted from the analytical investigation of the beam column joint with 1.5% basalt fiber reinforced beam column joint. Since the cyclic loading is applied at the beam column joint, the stiffness degrades at various cycle of load which is applied continuously. The hysteresis behaviour of 1.5% basalt fiber reinforced beam column joint shows that the joint is less stiff and more ductile. Therefore the basalt fiber reinforced joint fails at 80KN with 884.25 mm deflection.

1. The conventional beam column joint shows deflection of 3.08mm.
2. The basalt fiber reinforced beam column joint shows deflection of 884.25mm.
3. The conventional beam column joint shows stiffness value for load cycle 1 is 40.83 N/m and at the last cycle reduced to 22.73 N/m.
4. The basalt fiber reinforced concrete shows stiffness value for load cycle 1 is 0.0108N/m and at the last cycle reduced to 0.102 N/m.

CONCLUSION

Based on the analytical investigations carried out on the conventional concrete and basalt fiber reinforced concrete beam column joint the following conclusions were drawn.

1. The ultimate load of basalt fiber reinforced beam column joint is 1.5 times greater than the conventional beam column joint.
2. The deflection of basalt fiber reinforced beam column joint is 287 times greater than the conventional beam column joint.
3. The stiffness of basalt fiber reinforced beam column joint is 223 times lesser than the conventional beam column joint.

Since the basalt fiber reinforced beam column joint with 1.5% volume fraction shows more ductility and lesser stiffness under cyclic loading it is recommended in the beam column joint region on the structures. Therefore basalt fiber reinforced concrete will perform better in beam column joint to resist the lateral load and earthquake load on the structures.

REFERENCES

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