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# Studies on Strength Properties of RC Beam Column joint With Basalt Reinforcement

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**ABSTRACT:** In recent earthquakes it Is observed that the beam column joint is more exposed to lateral loads due to which the joints undergoes severe deformations leading to yielding of the joints and the overall structure. . Poor design practices for beam-column joints are compounded by the high demand imposed by adjacent flexural members (beams and columns) as they mobilize their inelastic capabilities to dissipate load energy. Unsafe design and details in the joint region put the entire structure at risk, even if other structural elements meet the design requirements. Therefore the new material that is basalt rebar is used as reinforcement to observe the structural behaviour of the beam column joint. The experiment is conducted and the results are taken. The comparative study is done by using both steel specimens and basalt reinforced specimens. The detailing is done as per the seismic codes. The results are tabulated and graph is plotted.

**KEYWORDS:** Beam-column joints, energy dissipation, Basalt rebar. Ductility, Load-Deflection.

## 1. INTRODUCTION:

The joints of beams columns in a reinforced concrete frame are crucial areas for the efficient transfer of loads between the connecting elements (i.e., beams and columns) of the structure. In the analysis of reinforced concrete moment frames, the Beam column junction is generally assumed to be rigid. In Indian practice, the joint is generally neglected for a specific design, with attention being limited to providing sufficient anchorage for longitudinal reinforcement of the beams. Poor design practices for beam-column joints are exacerbated by the substantial demand placed upon by adjacent flexural members (beams and columns) as they mobilize their inelastic capabilities to dissipate load energy. Unsafe design and details in the joint region put the entire structure at risk, even if other structural elements meet the design requirements. From three decades, wide-range of research has been carried out on the study of the response of joints under loading conditions through experimental and analytical studies. Several international codes of practice have undergone periodic reviews to integrate research findings into practice. Since the materials they are made of have limited strengths, the joints have a limited load capacity. When forces greater than this are applied, the joints are severely damaged. Repairing damaged joints is difficult and therefore damage must be avoided. Therefore, beam-column joints must be designed to resist sudden effects. In the event of seismic shaking, beams adjacent to a joint are subjected to moments in the same direction (clockwise or counter clockwise).

## 2. LITERATURE REVIEW:

**P. Rajaram, A. Murugesan And G.S. Thirugnanam:[2010] "**Experimental Study On Behaviour Of Interior Rc Beam Column Joints Subjected To Cyclic Loading" Six beam-column exterior joint specimens were molded with cross sections for beams and columns of 230 mm × 230 mm with a span of 1.25 m and a column height of 2 m. Parameters such as strength, stiffness, energy dissipation, hysteresis behavior and crack pattern were investigated. The strength, initial stiffness and energy dissipation of the ductile and non-ductile behavior of the beam-column connections showed higher strengths of 16.67% and 8.30% respectively. The ferrocement used to retrofit the samples increased the energy dissipation capacity and was observed to be more effective for reinforced joints between beams and columns in seismic regions.

**Monjusha Sarmah, Biswajit Roy, Ruhul Amin Mozumder, Aminul Islam Laskar**: "Effect Of Chopped Basalt Fibres On The Cyclic Behaviour Of Rcc Beam Column Subassemblies". [2017] Models such as crack patterns, hysteretic behaviour, ductility, stiffness, degradation and energy dissipation capacity were studied. Under cyclic loading, as a result of the formation of a hinge all specimens failed at the ending of the beam. The load capacity of all steel fiber reinforced samples and basalt fiber reinforced samples was higher than that of the control samples. Samples containing basalt fibers could exhibit less ductile behaviour than samples containing steel fibers for the entire fiber volume fraction.At initial, the stiffness of the BFRC samples decreased with increasing fiber volume fraction. In the SFRC samples, at initial the stiffness increased with increase in the fiber content.

**Sudip Chapagai , G. Premkumar [2017]** “Experimental Study On Size of the Effect Of R.C. Beam-Column Joint With And Without Hybrid Fibres Under Cyclic Loading” The large residual strain energy and dissipated energy in RC structures after earthquake-induced shaking constitute a major concern for the safety, durability, and maintainability of the structures. If the desired ductility can be given to the building, the seismic boundary force can be much smaller (up to 20%) than the corresponding force in an elastic building. The specimen assembly must possess adequate stiffness as well as strength to resist the internal forces induced by the structural elements. The beam-column connection is a critical area in a moment-resisting RC frame. Beam and column joints subjected to significant forces during ground movement and their behaviour have a significant impact on the response of the structure. An experimental study was attempted considering cutting without beam-column joints. They concluded that the energy dissipation gain per unit volume due to hybrid fibers and steel fibers is larger than that of the corresponding conventional samples and the existence of size effect also follows.

**Mohamed A. El Zareef , , Mohamed E. El Madawy [2018]** “Effect Of Glass-Fibre Rods On The Ductile Behaviour Of Reinforced Concrete Beams” They added Parameters such as Comparison of Moment Curvature, Load Behaviour – Deflection ,Conventional Ductility and Modified Ductility. Glass-Fibre reinforced beams reach their maximum moment just before breaking. However, it should be illuminated that Glass-Fibre reinforced beams are capable of presenting deformation characteristics comparable to those of steel reinforced beams before failure, with the only differentiated that they cannot maintain their maximum capacities for a long period of time before breaking. This can be attributed to the ideal elastic plastic behaviour of steel and the purely elastic behaviour of Glass-Fibre reinforced rods.

## 3. OBJECTIVES

- To carry out experimental study on crack formation in beam-column joint reinforced with basalt bars in comparison with traditional reinforced concrete beam column joint reinforced with steel.
- To evaluate the initial crack load and ultimate load of the beam column joint.
- To examine the Energy dissipation of the all the specimens.

**Details Of Test Specimen:**

| SL No | Specimen Details | No. of Specimen | Size of Specimen |
|---|---|---|---|
| 1 | Cubes | 06 | 150X150X150 |
| 2 | Beam Colum Joint | 04 | Column:1500X230X150<br>Beam: 1000X230X150 |

**Table No.1**

**Reinforcement Details of Beam-Column Specimen:**

| **Specimen Designation** | **Reinforcement Material** | **Beam Reinforcement** | | **Column Reinforcement** | |
|---|---|---|---|---|---|
| | | **Longitudinal** | **Transverse** | **Longitudinal** | **Transverse** |
| **S12** | Conventional Steel | Two No’s 8mmØ bars at top & Two No’s 12mmØ bars at bottom. Anchorage Length of 650mm at top & bottom bars. | 6mmØ at 45mm c/c for a distance of 360 mm from the joint and 80mm c/c for the remaining length. | Four No’s 12mmØ bars. | 6mmØ at 35mm c/c for a distance of 385mm at either side of the joint and 75mm c/c for the remaining portion. |
| **S10** | | Two No’s 8mmØ bars at top & Two No’s 10mmØ bars at bottom. Anchorage Length of 540mm at top & bottom bars. | | Four No’s 10mmØ bars. | |
| **B12** | | Two No’s 8mmØ bars at top & Two | 6mmØ at 45mm c/c for a distance | Four No’s 12mmØ bars | 6mmØ at 35mm c/c for a distance |

| | | | | | |
|---|---|---|---|---|---|
| | Basalt Rebars | No’s 12mmØ bars at bottom. Anchorage Length of 650mm at top & bottom bars | of 360 mm from the joint and 80mm c/c for the remaining length. | | of 385mm at either side of the joint and 75mm c/c for the remaining portion. |
| **B10** | | Two No’s 8mmØ bars at top & Two No’s 10mmØ bars at bottom. Anchorage Length of 540mm at top & bottom bars. | | Four No’s 10mmØ bars | |

**Table No.2**

All the four test specimens of beam-column assemblage are identical in size. The size of beam is 230mmX150mm. The column cross-section is 230mmX150mm. The dimension of the beam along the longitudinal direction is 1000mm from the column face and the height of the column is 1500mm. In the present study the reinforcement material used are conventional steel and basalt rebars.

i. **For 12mm:** The Specimen is designed according to IS: 13920:2016. Reinforcement provided in the beam is, 2 No’s of nominal bar of 8mm on the top and 2 No’s of main bar of 12 mm at the bottom. The stirrups are 6 mm diameter bars at 45 mm c/c for a distance of 2d, i.e., 360 mm from the inner edge of the column and at 80 mm c/c for remaining length of the beam. Top and Bottom bars belonging to the beam are provided with the anchorage length beyond the inner face of the column for a length of 650mm. Longitudinal reinforcement is provided at the column is, 4 No’s of main bars of 12mm. The column confinements are 6mm diameter bars at 35mm c/c for a distance of 385mm at either aspect of the joint and 75mm c/c for remaining segment of the column.

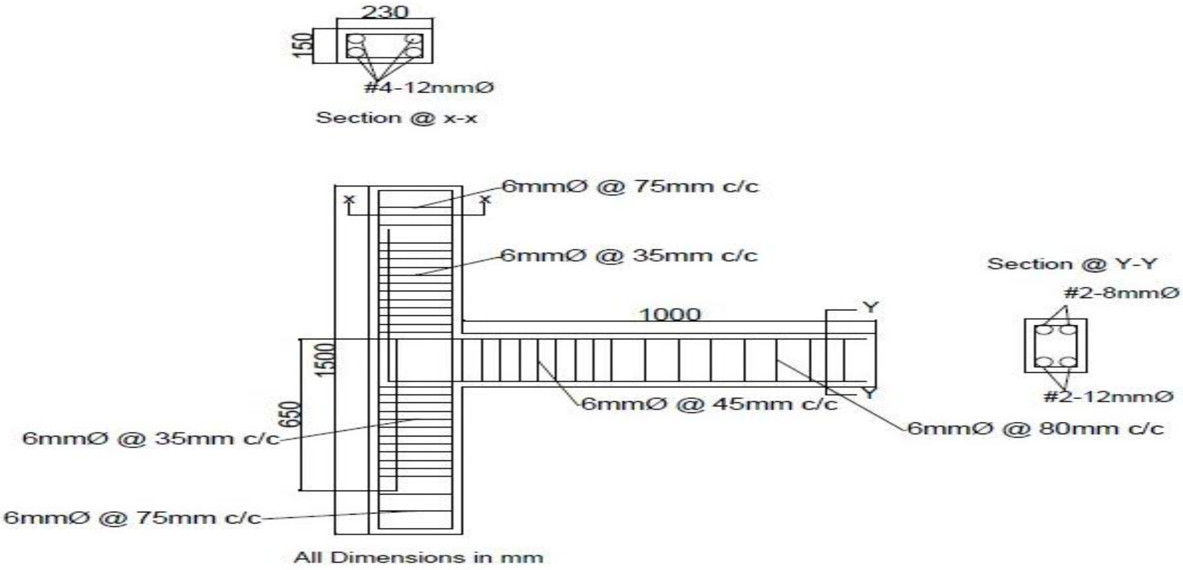


**Fig No.1**

i. **For 10mm:** Reinforcement provided within the beam is, 2 No’s of nominal bar of 8mm on the top and 2 No’s of main bar of 10 mm at the bottom. The stirrups are 6 mm diameter bars at 45 mm c/c for a distance of 2d, i.e., 360 mm from the peripheral of the column and at 80 mm c/c for the rest of the length of the beam. Top and Bottom bars belonging to the beam are provided with the anchorage length beyond the inner face of the column for a length of 540mm. Longitudinal reinforcement provided in the column is, 4 No’s of main bars of 10mm. The column confinements are 6mm diameter bars at 35mm c/c for a distance of 385mm at either aspect of the joint and 75mm c/c for remaining segment of the column.

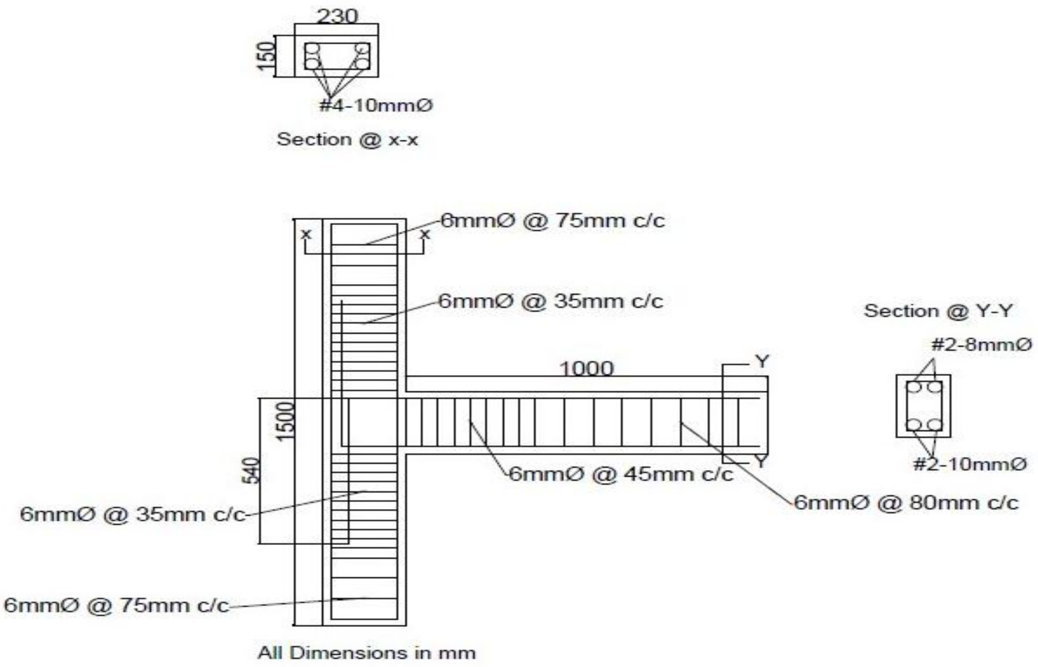


**Fig No.2**

**Fig No.3 Conventional Steel Reinforcement of Beam-Column**

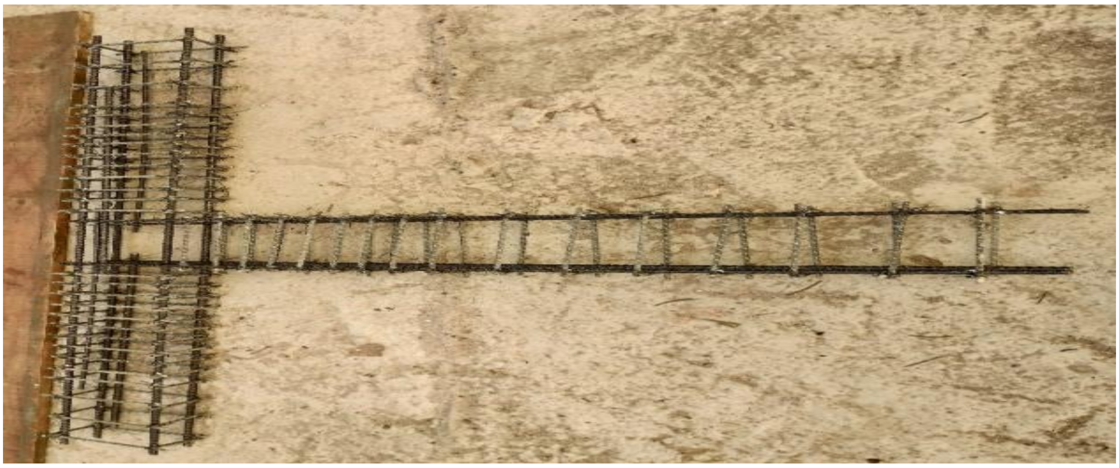


**Fig No.4 Basalt Reinforcement of Beam-Column**

### Experimental Setup

The beam column joint study has been restricted to consider the readings until the crack reaches to compression zone, as soon as the crack reaches to compression zone the loading is stopped and the load and its respective deflection readings are recorded. the reading is noted at every incremental increase of load borne from the Proving ring and deformations are measured from the dial indicator guage of 25mm capacity with its least reading being 0.01 mm. Beam column joint is one of the most critical regions in the structure because when this region is weak due to development of Plastic hinges, there is likely a chance of damage at the roofs that may be adequately designed .The point of contra flexure lies at the beam and column joint. Since the loading from the bottom, hence in the beam the bottom fibre will be experience the tension stresses and the top fibres in the beam will experience the compression. The loading arrangement is as shown, fig.No 4.

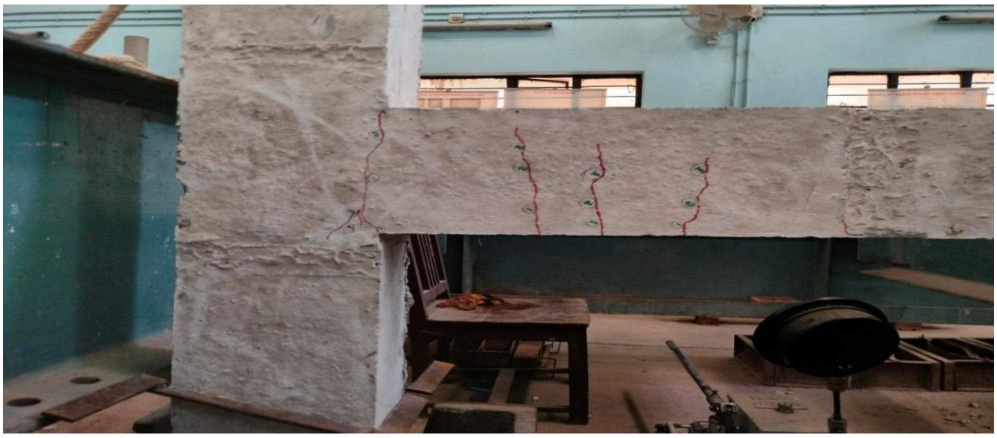


**Fig No.5**

The beam column joint arrangement has been made to only position restrained. it means the specimen can be subjected to lateral movement or movement being generated. Since there is less data available regarding the beam column joint and also the unavailability of experimental results being conducted therefore, with the available data we could manage to restrain the column only in position.

Beam column joint with 10mm Steel bars

Beam column joint with 12 mm Steel bars

In this figure we can clearly see the cracks have reached to the compression zone in the junction between beam and column, whereas the other cracks formed near the joint are also visible and highlighted. The load at which initial cracks are formed and the deflection observed are mentioned in the tableNo.3 .The cracks were formed maximum near the joint and less away from the joint.

**Fig No.6**

In this figure the cracks are seen which are generated from the beneath of the beam and then reached to the compression zone consequently. The cracks formed were noted down by marking them as shown in the fig.no 8 . The values of load and deflection are mentioned in the table below.

Beam column joint with 10 mm Basalt bars

**Fig No.7**

The cracks formed in the basalt rebar reinforced beam column joint are as shown. We can observe the higher crack widths and are having higher ductility index in comparison with the steel reinforced specimens. The values are mentioned in the table No.3.

Beam column joint with 12 mm Basalt bars

**Fig No.8**

The cracks in the specimen with basalt beam column joint originated from the bottom of the beam and cracks also reached the column face. The major difference between steel and basalt rebar is the propagation of cracks after formation of first crack.

## 4. RESULTS AND DISCUSSIONS

### 1] Initial Crack Load & Ultimate Load :

- The initial crack load for the basalt rebar occurred earlier than the steel rebar since basalt rebar possess lower yield strength, making them undergo deformations under minimum loading leading to early cracks than steel rebar.
- The ultimate load carrying capacity of the steel rebar of both the diameter appears to be performing better under loading.
- The post cracking behaviour of 10mm basalt rebar appears to be better as the time available fro initial to ultimate crack load is more than in steel 10mm specimen. This would be better parameter in serviceability aspect of design. Whereas the time available from initial to ultimate load in 12mm specimens is similar.

**Table No.3**

| | **Initial L&D** | | **Final L& D** | | **Results** | | |
|---|---|---|---|---|---|---|---|
| **material** | **Load** | **deflection** | **Load** | **deflection** | **Diff in Load** | **Diff in deflection** | **Ductility factor/index** |
| Basalt 10 | 18.37 | 11.8 | 31.73 | 29.65 | 13.36 | 17.85 | 2.51 |
| steel 10 | 31.73 | 14.5 | 41.75 | 21 | 10.02 | 6.5 | 1.45 |
| Basalt 12 | 13.36 | 7.65 | 33.4 | 23.5 | 20.04 | 15.85 | 3.07 |
| Steel 12 | 20.04 | 12 | 46.76 | 27.85 | 26.72 | 15.85 | 2.32 |

**2] Load v/s Deflection :**

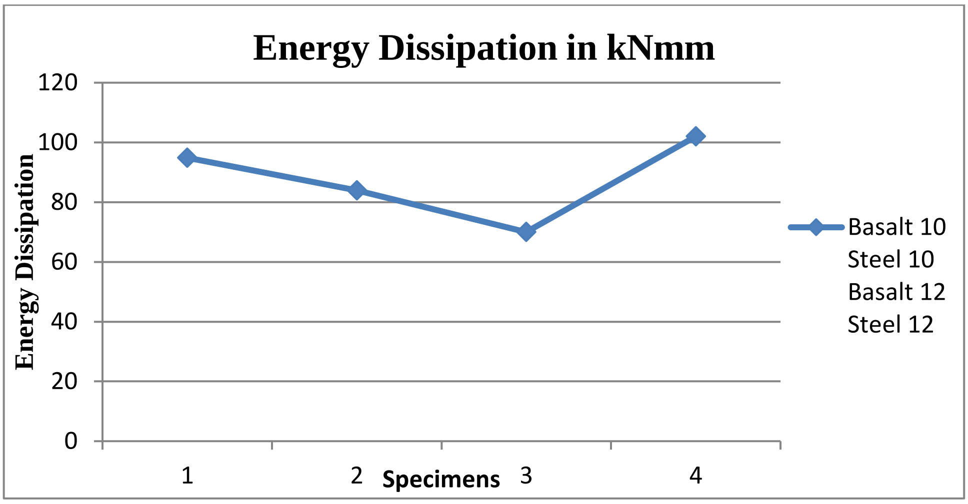
- Literature has always shown, whenever concrete is mixed or combined with fibers as reinforcement, better outcome are always obtained in many parameters such as crack bridging effect, better tensile load capacity or higher ductility. On basis of these facts, the basalt-reinforced specimen should also perform regard to of load capacity based on its yield strength capacity in contrast to the yield strength criteria of the steel-reinforced specimens.
- Basalt-reinforced beam column specimens reach their maximum moment capacity just before failure. However, it should be noted, basalt-reinforced beams are efficient of presenting deformation characteristics comparable to those of steel-reinforced beams before the ineffectiveness, with the only differentiation being that they are unable to maintain maximum capacities for a long period of time before breaking. This is due to the ideal elastic plastic behaviour of steel and the purely elastic behaviour of basalt bars.
- The high deformation of the basalt-reinforced specimens can be attributed to the fact that the rods are efficient of undergoing quite large deformations prior to reaching the ultimate strength of a very high value, which rarely occurs. It can be stated that at a high reinforcement rate, the differentiation between the max deflection values before the non-positive outcome of the basalt-reinforced samples and the steel-reinforced samples will be smaller than the low reinforcement rate.
- It is clear from the graph that the graphs are bilinear in nature and the 10mm basalt rebar is less rigid than the 10mm steel rebar, making it more deformable. Basalt and 12 mm steel rebar show similar stiffness behaviour because they have a very linear curve on the graph.

**3] Energy Dissipation:**

- Energy dissipation capacity is important to estimate the earthquake force resistance of a structure. A structure can only withstand strong ground waves caused by earthquakes if it has sufficient capacity to dissipate the seismic energy. The area under the load-displacement hysteresis loop represents the energy expended in every loading cycle.
- The dissipation values are found to be satisfactory with the specimens having basalt rebars by considering the exact yield stress of the basalt rebar. Both the 10 mm and 12mm diameter basalt rebar specimens are found to be performing better than steel rebars .

**Table No.4**

| Material | Energy Dissipation In KNmm | Equivalent yield stress criteria in KNmm |
|---|---|---|
| Basalt 10 | 94.9 | 146.14 |
| Steel 10 | 84 | 84 |
| Basalt 12 | 70 | 107.8 |
| Steel 12 | 102 | 102 |



Graph No.1

### 4] Ductility

- Ductility is a safety parameter, as it allows stress redistribution and it is very helpful structural property. In general when ductility ratio is higher, it indicates structural member can undergo considerable deformations before structure gets damaged.
- The ductility index is described as the way they associated with the ultimate deflection and the deflection at the failure of the reinforcing bar in tension.
- Ductility ratio = *Ultimate deflection* | *Initial yielding deflection*
- To describe as the general evaluation method of ductility index, the curvature, rotation and deflection relationships can be stated as strain, as showed in Eqn. In this experiment, the ductility index was examined using the ductility relationship via deflection on basis of the outcome of the load-displacement test.

### 5] Crack Pattern & Propagation

The specimen reinforced by steel and basalt rebar found to develop flexural cracks along with shear cracks, but the specimens reinforced by steel rebar were governed by flexural cracks on the beams& specimen with basalt rebar were governed by shear cracks found at the joint /junction of beam column specimen and flexural cracks on the beams.

## 5. CONCLUSION

1] The Steel specimen with 10/12 mm bars though carried higher loads than basalt 10/12 mm specimens, but specimens with the basalt rebar deformed more than steel rebar, the energy absorbing capacity of basalt specimen is comparatively more than steel rebar, w.r.t serviceability criteria this behaviour of basalt rebar is most favourable as it gives clear indication of rupture & also enough time for room evacuation.

2] The ductility index of basalt rebar is comparatively performing better than the steel rebar as indicated in the table No.3. as contrasts to the behaviour of the FRP materials , since the shear reinforcement used are also basalt rebar , the behaviour of basalt rebar when used as stirrups proved to give better results , this implies that main reason to increase the ductility index of the basalt rebar.

3] As the increased Ductility index of the basalt rebar is found, with the increase of reinforcement ratio thus giving better results consequently.

4] From the observations it is clear that from the equivalent yield stress criteria, the energy dissipation capacity of the basalt rebar specimen is performing better than steel specimens.

In condition of 10mm rebar, basalt rebar is providing 74% of enhanced energy dissipation characteristics, whereas in case of 12mm rebar basalt rebar is providing 5% of enhanced energy dissipation characteristics.

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