# STUDY ON BEAM-COLUMN JOINTS

**R.V. Saravana harish[1], C. Subramanian[2]**

[1]M.E. Scholar, Alagappa Chettiar Government College of Engineering and Technology, Karaikudi-630 003, Tamilnadu, India

[2] Assistant Professor, Alagappa Chettiar Government College of Engineering and Technology, Karaikudi-630 003, Tamilnadu, India

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**Abstract -** *A beam-column joint is a very critical zone in reinforced concrete framed structure where the elements intersect in all three directions. Joints ensure continuity of a structure and transfer forces that are present at the ends of the members. In reinforced concrete structures, failure in a beam often occurs at the beam-column joint making the joint one of the most critical sections of the structure. Sudden change in geometry and complexity of stress distribution at joint are the reasons for their critical behaviour. In early days, the design of joints in reinforced concrete structures was generally limited to satisfying anchorage requirements. The behaviour of joints was found to be dependent on a number of factors related with their geometry; amount and detailing of reinforcement, concrete strength and loading pattern.*

*IS Code 13920, 'Ductile detailing of reinforced concrete structures subjected to seismic forces' suggested special confining reinforcement in beam and column near beam-column joint to increase its performance under cyclic loading during earthquake*

*In this project, an attempt is made to study of the behavior beam-column joints with and without confining reinforcement, under cyclic loading. Exterior beam-column joints with and without confining reinforcement was designed and detailed according to IS 13920 and IS 456 respectively. The joints were cast and tested under cyclic loading to study Load-deflection behavior, Load-displacement hysteresis, ductility behavior, stiffness behavior and crack pattern.*

*It is observed from this study that the beam-column joint detailed with special confining reinforcement according to IS 13920shows better results when compared to the one without special confining reinforcement, designed according to IS 456*

***Key Words***: Beam column Joint, cyclic loading.

## 1.INTRODUCTION

A beam-column joint is a very critical zone in reinforced concrete framed structure where the elements intersect in all three directions. Joints ensure continuity of a structure and transfer forces that are present at the ends of the members. In reinforced concrete structures, failure in a beam often occurs at the beam-column joint making the joint one of the most critical sections of the structure. Sudden change in geometry and complexity of stress distribution at joint are the reasons for their critical behaviour. In early days, the design of joints in reinforced concrete structures was generally limited to satisfying anchorage requirements. In succeeding years, the behaviour of joints was found to be dependent on a number of factors related with their geometry; amount and detailing of reinforcement, concrete strength and loading pattern

### 1.1. Beam column joints

The functional requirement of a joint, which is the zone of intersection of beams and columns, is to enable the adjoining members to develop and sustain their ultimate capacity. The joints should have adequate strength and stiffness to resist the internal forces induced by the framing members.

### 1.2. Requirements of beam column joints

The requirements Criteria for the desirable performance of joints can be summed up as:

(i)The strength of the joint should not be less than the maximum demand corresponding to development of the structural plastic hinge mechanism for the frame. This will eliminate the need for repair in a relatively inaccessible region and for energy dissipation by joint mechanisms, which, as will be seen subsequently, undergo serious stiffness and strength degradation when subjected to cyclic actions in the inelastic range.

(ii) The capacity of the column should not be jeopardized by possible strength degradation within the joint. The joint should also be considered as an integral part of the column.

(iii)The joint reinforcement necessary to ensure satisfactory performance should not cause undue construction difficulties.

### 1.3. Objective

The main objective of the study is to design the beam-column joint in accordance with IS456 and IS13920 and to obtain the optimum design of the joint by increasing the stiffness of the joint and by doing proper detailing of the reinforcement. Initially a G+2 building is taken and designed for response spectra in STAAD Pro.

### 1.4. Autocad modelling

An AUTOCAD plan was drawn for an area 4500 sq. ft. was drawn for G+2 building.

**Table.1**

| PARAMETER | DESIGN VALUES |
|---|---|
| Plot Area | 4500 sq. ft. |
| Height of the building | 12 m |
| Length of the building in X-direction | 19.89m |
| Length of the building in Z-direction | 21.72m |
| Building location | Chennai |

## 2. ANALYSING USING STAAD PRO

The drawn AUTOCAD plan of G+2 is modelled in STAAD Pro and analysed.

**Table.2**

| PARAMETER | DESIGN VALUES |
|---|---|
| Plot Area | 4500 sq. ft. |
| Height of the building | 12 m |
| Length of the building in X-direction | 19.89m |
| Length of the building in Z-direction | 21.72m |
| Building location | Chennai |
| Zone | III |
| Zone factor | 0.16 |
| Importance factor | 1 |
| Response reduction factor | 5 |
| Seismic method | Response Spectrum method |
| Grade of steel | Fe500 |
| Grade of concrete | M30 |

### 2.1. Modelling of G+2 structure

The G+2 Building was modelled in the STAAD Pro based on the building parameters that were specified in the according to the building zone factors for further analysis the building based on the method of Response spectrum method.

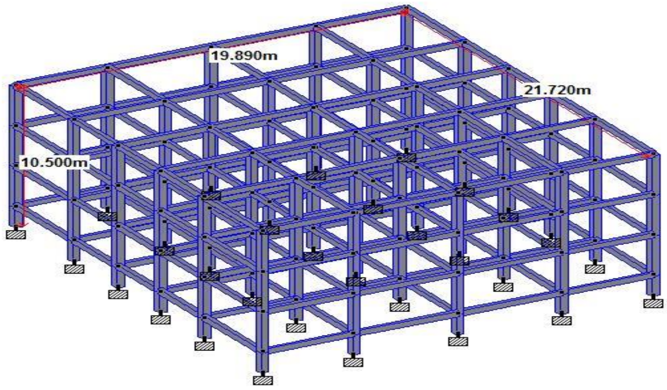


**Fig.1. G+2 Model**

### 2.2. Load combinations

The actions of loads on the building are shown in the following figures followed by the load combinations that were used in analysing the building and the load combinations were considered in accordance with IS 1893. The load combinations that were used are as follows,

1. 1.1.5(D.L+IL)

2.1.2(DL+IL+EL)

3. 1.2(DL+IL-EL)

4.1.5(DL+EL)

5. 1.5(DL-EL)

6.0.9DL+1.5EL

7. 0.9DL-1.5EL

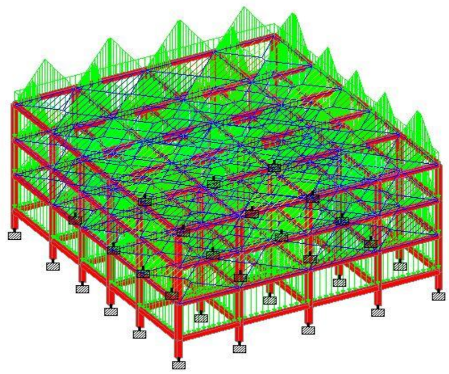

**Fig.2. Dead Load- self weight of the G+2**

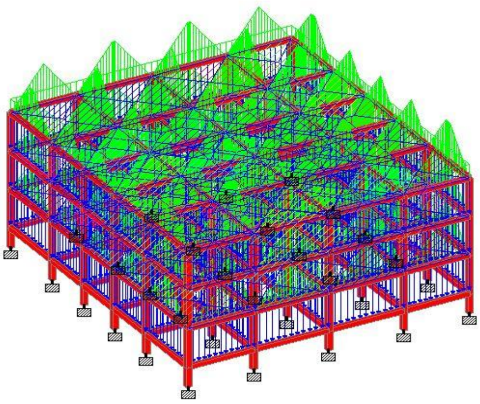

**Fig.3. Dead Load- Brick load of the G+2**

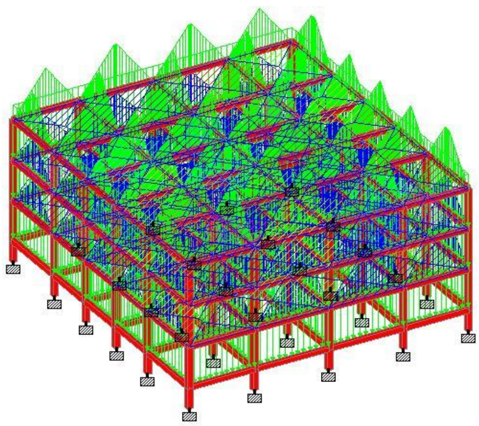

**Fig.4. Live Load for G+2**

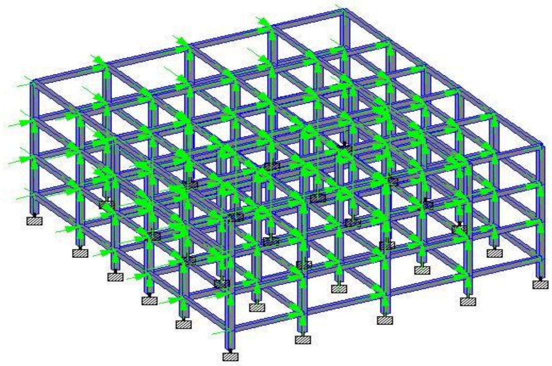

**Fig.5. Joints loads**

### 2.3. Beam column joint

A Exterior beam column joint was taken from the building was taken from the staad model.

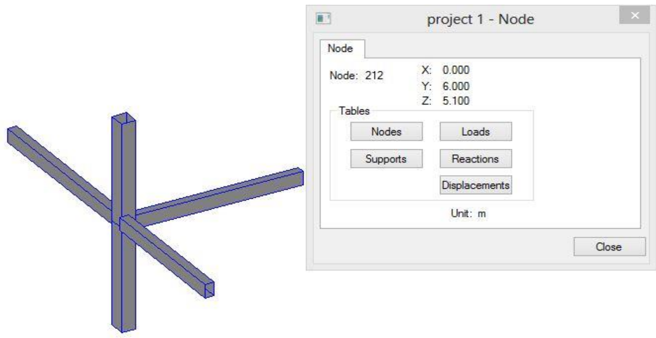


**Fig.6. Beam column Joint**

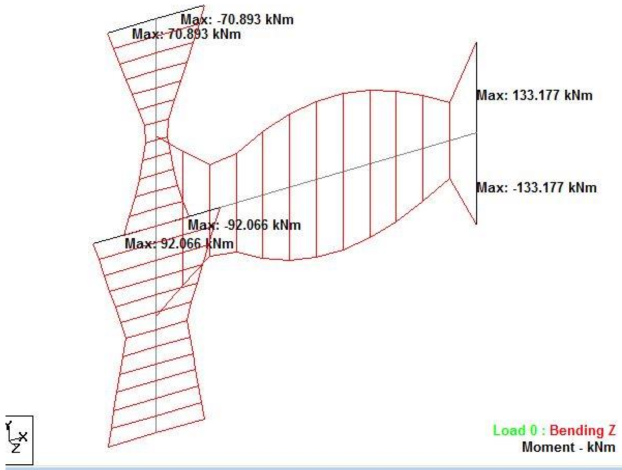


**Fig.7. Bending Moment for the beam column Joint**

### 2.4. Analysis of structure

Dynamic analysis shall be performed to obtain the design seismic forces, and its distribution to different levels along the height of the building and to the various lateral load resisting elements.

Dynamic analysis may be performed either by time history analysis method or response spectrum method. The value of damping for the buildings may be taken as 2 and 5 percent of the critical, for the purposes of dynamic analysis of steel and reinforced concrete buildings respectively.

**Table.3**

| **PARAMETER** | **DESIGN VALUES** |
|---|---|
| Plot Area | 4500 sq. ft. |
| Height of the building | 12 m |
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| Building location | Chennai |
| Zone | III |
| Zone factor | 0.16 |
| Importance factor | 1 |
| Response reduction factor | 5 |
| Seismic method | Response Spectrum method |
| Grade of steel | Fe500 |
| Grade of concrete | M30 |
| Method of Analysis | CQC method |

### 2.5. Experimental setup

Both the specimens were tested in reaction frame of 50 tons capacity. The test setup is shown in fig 19. Hydraulic jack was used to apply the load at the free end of the beam in both upward and downward directions individually. To record the load precisely a load cell was used. Each beam-column joint specimen was tested under cyclic loading in the predetermined load sequence. The column was centered accurately to avoid eccentricity. An axial load of 100KN was applied on the column by means of 50ton hydraulic jack. Hand operated screw jacks of 5ton capacity were used to apply the forward and reverse loading over the beam portion. Linear Variable Differential Transformer(LVDT) was used to measure the downward and the upward displacement in the beam and fixed at a distance of 500mm clear of the column.

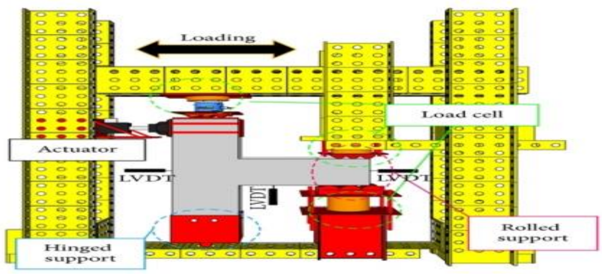


**Fig.8. Experimental setup**

### 3. RESULTS & DISCUSSSION

The result of the test were conducted to evaluate the strength and ductility of beam-column joints are presented in this chapter. The influence of ductility is 1

### 3.1. Load deflection behaviour

The ultimate load carrying capacity of the control beam-column joints specimen are listed in table 1.

**Table 4.**

| s.no | specimen | Forward | | Reverse | |
|---|---|---|---|---|---|
| | | Ult. load KN | Ult. Def. mm | Ult. load KN | Ult. Def. mm |
| 1 | IS13920 | 36 | 36.77 | 28.22 | 18.33 |
| 2 | IS456 | 21 | 15.10 | 10.12 | 18.59 |

### 3.2. Load-displacement hysteresis loop

The load vs lateral displacements plot for the test specimen, also referred to as hysteresis loop are shown in figure.

The load-displacement hysteresis loop for all specimen is shown in figure. Hysteresis loops were observed with large energy dissipation capacity it can be seen that ultimate load carrying capacity is higher for specimen with reinforcement as per IS13920. From the above plots it can be seen that the specimen with reinforcement from IS456 suffered maximum displacement.

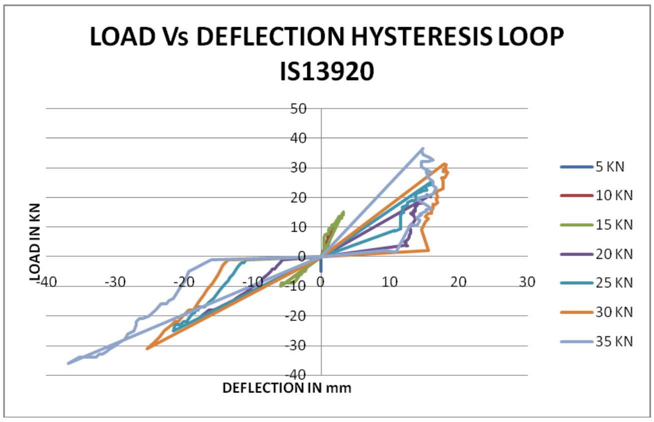


**Fig.9. hysteresis loop for IS13920**

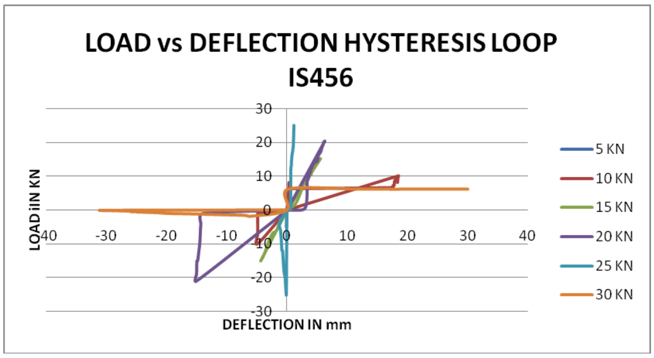


**Fig.10. hysteresis loop for IS456**

### 3.3. Ductility behaviour

Ductility of a structure is its ability to undergo deformation beyond the initial yield deformation, while still sustaining load. In this investigation ductility factories defined as the ratio of maximum deflection obtained in each cycle to the yield deflection. The ductility factor μ, a measure of ductility of structure is defined as the ratio of $\Delta_u$and $\Delta_y$where $\Delta_u$and $\Delta_y$are the respective lateral deflection as the end of the post elastic range and when the yield is first reached.

Displacement ductility $\mu = \Delta_u/\Delta_y$

It is observed that the peak value of displacement ductility has been exhibited by the specimen with reinforcement as perIS13920. A lower value of ductility was consistently observed for the specimen with reinforcement as per IS456.

### 3.4. Stiffness behaviour

Stiffness is also the main variable controlling safety against instability. Stiffness is defined as the load required to causing unit deflection of the beam-column joint. The stiffness of the beam-column joint is approximated as slope of the peak to peak line in each loading cycle. The variation of stiffness in each cycle corresponding to the maximum displacement in that cycle is calculated and is shown in tables

**Table.5. Stiffness behaviour of IS 13920& IS456**

| S.NO | LOAD KN | STIFFNESS FACTOR IN KN/mm | | | |
|---|---|---|---|---|---|
| | | FORWARD | | REVERSE | |
| | | **IS13920** | **IS456** | **IS13920** | **IS456** |
| 1 | 5 | 160.77 | 34.8 | 4.255 | 13.13 |
| 2 | 10 | 1.69 | 2.03 | 5.97 | 0.537 |
| 3 | 15 | 2.54 | 3.41 | 4.74 | 2.711 |
| 4 | 20 | 1.14 | 1.32 | 1.309 | 3.21 |
| 5 | 25 | 1.16 | 19.78 | 1.56 | 20.537 |
| 6 | 30 | 1.18 | 16.20 | 1.7 | 4.937 |
| 7 | 35 | 0.95 | | 2.36 | |

### 3.5. Cracking pattern and failure mode

In the beam-column joints, compression and tension developed in joint region during cyclic loading and the bond between concrete and reinforcement was consequently reduced consequently. The first crack occurred near the beam-column joint and with further increase in loading the cracks propagated and initial cracks started widening. The crack pattern of the specimens will be discussed below.

The first crack was witnessed at the load level of 18kN for specimen with reinforcement as per IS13920. As the load level was increased, further cracks were developed in other portions of the beam. Crack width at failure load was 0.9mm

Fig.11. Crack pattern for specimen detailed as per is 456

**Table.6**

| Specimen | 1st crack Load KN | Deflection mm | Crack width mm |
|---|---|---|---|
| IS 13920 | 18 | 17.4982 | 0.5 |
| IS 456 | 15 | 5.5322 | 0.7 |

### 4. CONCLUSION

In this project, an attempt was made to study the behaviour of the beam column joint under seismic loading, in which the reversal of loading in structure is taken into consideration.

The project was carried out after a detailed study of the codal requirements and on-site detailing irregularities that is done currently in the field.

A real time G+2 Building located in Chennai (zone III) is been taken and analysed for response spectrum method in STAAD Pro. Two beam-column joints were casted one by providing reinforcement as per the guidelines given by IS 13920 and the other by the guidelines given by IS 456. They were experimentally studied by taking ductility factors into account.

The specimen detailed using IS 13920 took 7 cycles of load but the specimen detailed as per IS 456 took only 6 cycles of load.

The ultimate load that the specimen detailed as per IS 13920 could take is 35KN whereas the specimen detailed by IS 456 could take only 30KN.

Similarly, the stiffness factor for the specimen detailed as per IS 13920 is 4.255 and that for IS 456 is 3.21.

Comparing the crack width and the crack pattern the specimen detailed by IS 13920 is 0.9mm and for IS 456 is 1.2mm.

It is learnt from the final experiment that beam-column joint designed by the guidelines given by IS 13920 with special reinforcement taking ductility considerations proves to be better than the one designed by the guidelines given by IS 456.

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