International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 08 | Aug 2020 www.irjet.net p-ISSN: 2395-0072

# STUDY ON BEHAVIOUR OF EXTENDED END-PLATE BOLTED CONNECTIONS SUBJECTED TO CYCLIC LOADING

**Aiswarya Sathian[1], Geetha P R[2]**

*[1]M-Tech Student, Dept. of Civil Engineering, Thejus Engineering College, Kerala, India*
*[2]Assistant Professor, Dept. of Civil Engineering, Thejus Engineering College, Kerala, India*

---------------------------------------------------------------------***---------------------------------------------------------------------

**Abstract -** *Extended end-plate bolted connections are widely used in the steel frames exposed to seismic or cyclic loads. It exhibits the stiffness, the strength and the ductility required for connections in seismic zones. In this study, a comparative study has been carried out, with and without end-plate stiffeners, in which the thickness and number of end-plate stiffeners varying and are modelled and analyzed using finite element software ANSYS. All the models have been subjected to cyclic loading. The effects of vertical and horizontal side stiffeners on the static behaviour of the semi-rigid beam-to-column bolted connections were studied. The use of end-plate stiffeners and side stiffeners in extended end-plate bolted connections results in increased load carrying and moment carrying capacity. The behaviours of varying height beam column interior joints were discussed.*

***Key Words***: **Extended end-plate, Bolted beam-column connection, Finite Element Analysis, Finite Element, End-plate stiffener, Side-stiffener, Varying beam height.**

## 1. INTRODUCTION

End-plate moment connections have become more popular due to ease of fabrication and erection. It became the most widely used connection in the construction of metal buildings and steel portal frames. The use of bolted end-plate moment connections is to connect a beam to-column or to splice two beams together. A typical moment end-plate connection is composed of a steel plate welded to the end of a beam section with attachment to an adjacent member using rows of fully tensioned high-strength bolts. The connection may join a beam and a column or two beams. End-plate moment connections are classified as either flush or extended, with or without stiffeners, and further classified depending on the number of bolts at the tension flange. A flush connection is detailed such that the end plate does not extend beyond the beam flanges and all bolts are located between the beam flanges. Flush end-plate connections are typically used in frames subject to light lateral loadings or near inflection points of gable frames. An extended connection is detailed such that the end plate extends beyond the tension flange a sufficient distance to allow a location of bolts other than between the beam flanges. Extended end plates may be used with or without a stiffener between the end plate and the tension beam flange in the plane of the beam web. Extended end-plates are used for beam-to-column moment connections.

### 1.1 EXTENDED END-PLATE BOLTED BEAM-TO-COLUMN CONNECTIONS

Moment resisting connections are used in single-storey portal frame buildings and in multi-storey un-braced buildings. Connections in multi-storey frames are most likely to be bolted, full depth end plate connections or extended end plate connections. The most commonly used moment resisting connections are bolted end plate beam-to-column connections. The end plate, which may be partial depth or full depth, is welded to the supported beam in the workshop. The beam is then bolted to the supporting beam or column. Fig- 1 shows typical extended end-plate connection.

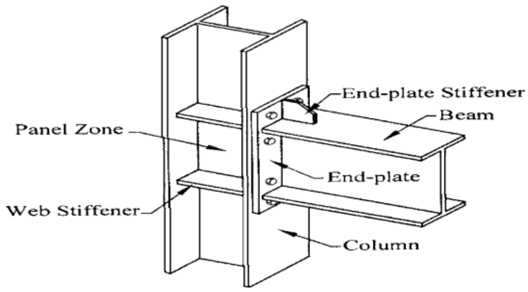



**Fig-1** Typical extended end-plate connection

## 2. OBJECTIVES OF THE WORK

- To study the hysteresis behaviour of extended end-plate bolted connections with and without stiffeners in interior joints.
- To study the hysteresis behaviour of extended end-plate bolted connections with horizontal and vertical side stiffeners in interior joints.
- To study the hysteresis behaviour of extended end-plate bolted connections in joints with beams of varying height.

## 3. STUDY OF END-PLATE CONNECTIONS WITH AND WITHOUT STIFFENERS

A total of four specimens were studied by changing number of end-plate stiffeners in top and bottom sides of the beams. The models are as follows:

1. Interior joint without stiffener (IJ)
2. Interior joint with stiffener 1-1(IJS 1-1)
3. Interior joint with stiffener 2-1 (IJS 2-1)
4. Interior joint with stiffener 2-2 (IJS 2-2)

In all specimens, the length of beam and column were 1,600 and 1,800 mm, respectively. The thickness of the end-plate is 12mm. The beam was connected to the column by means of extended end-plate connections with eight high-strength bolts (M20, grade 10.9, yield stress *fy* is 960 N/mm2, ultimate stress *fu* is 1,040 N/mm2). The dimensions of member sections are shown in Table-1.

**Table -1:** Dimensions of member sections

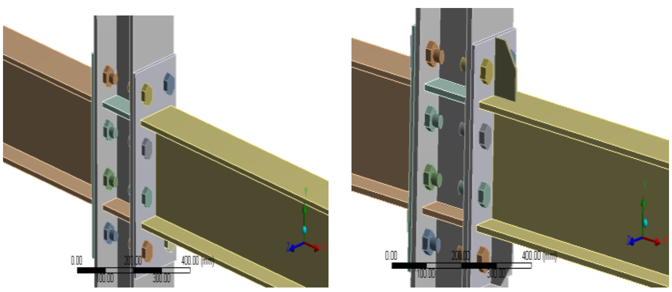
| Members | Thickness of flange $t_f$ (mm) | Thickness of Web, $t_w$ (mm) | Width of flange (mm) | Height (mm) |
|---|---|---|---|---|
| Beam | 10 | 6 | 150 | 200 |
| Column | 18 | 12 | 200 | 200 |

A non linear static analysis was done in ANSYS workbench 16.1 software for beam column connection. The column, beam, end-plate, web stiffener, end-plate stiffener and bolts were modeled using solid186 element and the meshes used are triangular and rectangular mesh. The geometrical specifications of extended end-plate beam-column joint are shown in Table-2. The geometrical models of with and without end-plate stiffeners are shown in Figure 2.

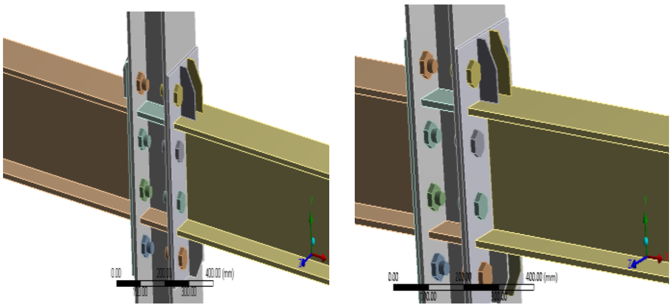
**Table -2:** Geometrical specifications of models

| Models | Thickness of end-plate stiffeners(mm) | End-plate stiffeners at | |
|---|---|---|---|
| | | Top section | Bottom section |
| IJ | - | 0 | 0 |
| IJS 1-1 | 3 | 1 | 1 |
| IJS 2-1 | 1.5 | 2 | 1 |
| IJS 2-2 | 1.5 | 2 | 2 |

Top of the column was restrained only in X and Y directions, while the movement in the Y direction was allowed. The bottom end of the column was restrained in the three direction of X, Y and Z. The cyclic loading was applied with equal magnitude and opposite direction on both ends of the beams to simulate the horizontal seismic action.



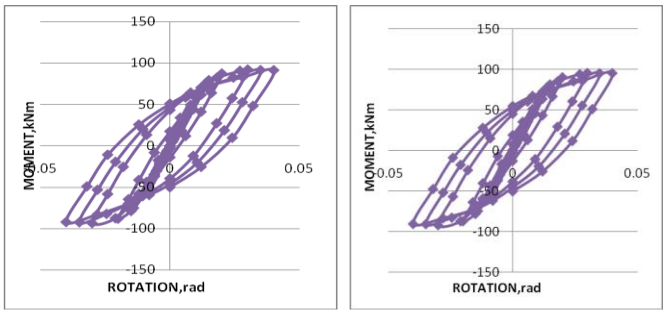
(a) (b)



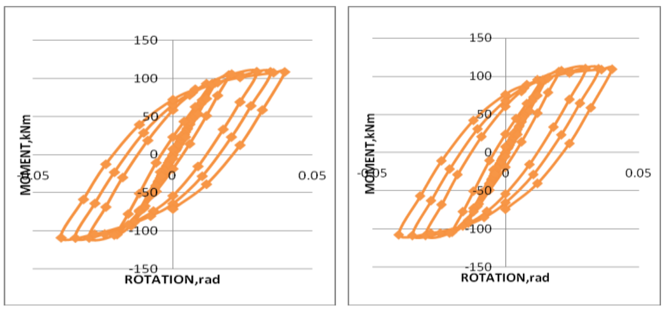
(c) (d)

**Fig-2** Models (a) IJ (b) IJS 1-1 (c) IJS 2-1 (d) IJS 2-2

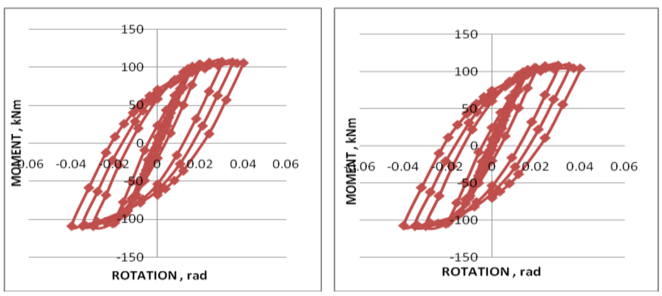
The models were used to analyse the cyclic loading behaviour by studying the equivalent stress distribution, deformation, and load and moment carrying capacity. Moment-rotation hysteresis loops for left and right side beams of bolted beam column connections are showed in chart-1.



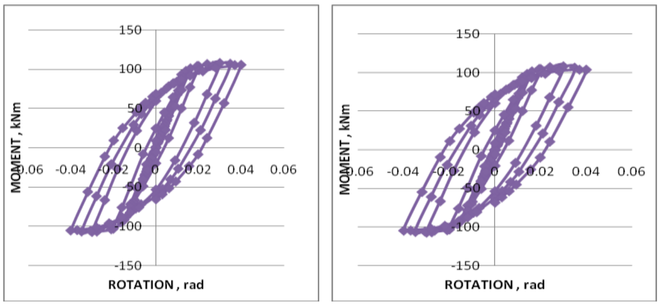

(a) IJ




(b) IJS 1-1




(c) IJS 2-1




(d) IJS 2-2

**Chart -1**: Moment – Rotation hysteresis loops for left and right side beams

Here the stiffened IJS 1-1, IJS 2-1, IJS 2-2 shows higher moment carrying capacity than IJ. IJS 1-1 showed an increase of 15% in moment carrying capacity when compared with IJ. Whereas other connections such as IJS 2-1, IJS 2-2 shows an increase of 13.3% and 13.2% respectively. From the study it was found that beam column connection made by stiffened beam sections showed higher load carrying capacity than unstiffened connection. When considering the IJ as the base model, IJS 1-1 showed an increase of 15% in load carrying capacity. Whereas IJS 2-1, IJS 2-2 showed an increase of 13.3% and 13.2% respectively.

## 4. STUDY ON END-PLATE BEAM COLUMN JOINTS WITH HORIZONTAL AND VERTICAL SIDE STIFFENERS

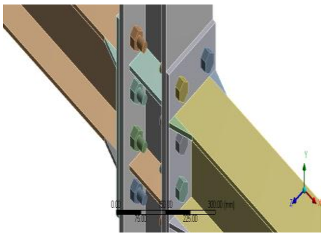
A total of six specimens were studied by changing length of the side stiffeners. The behaviours of interior joint with vertical and horizontal side-stiffeners were compared.

1. Interior joint with side stiffner-75 mm-H (IJ-SS-75-H)
2. Interior joint with side stiffner-100mm-H (IJ-SS-100-H)
3. Interior joint with side stiffner-125mm-H (IJ-SS-125-H)
4. Interior joint with side stiffner-75mm-V (IJ-SS-75-V)
5. Interior joint with side stiffner-100mm-V (IJ-SS-100-V)
6. Interior joint with side stiffner-150mm-V (IJ-SS-150-V)

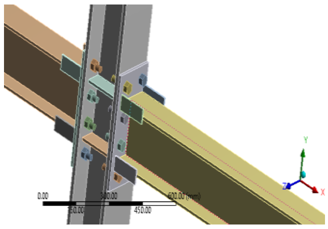
The height of the column and length of the beam is kept constant in all the models. Extended end-plate bolted connections with side stiffeners are shown in Fig 3 and Geometric specifications of models are given in Table 3.

**Table -3:** Geometrical specifications of models

| Models | Direction of side stiffener | Side stiffener length (mm) | Side stiffener thickness(mm) |
|---|---|---|---|
| IJ-SS-75-H | Horizontal | 75 | 10 |
| IJ-SS-100-H | Horizontal | 100 | 10 |
| IJ-SS-125-H | Horizontal | 125 | 10 |
| IJ-SS-75-V | Vertical | 75 | 6 |
| IJ-SS-100-V | Vertical | 100 | 6 |
| IJ-SS-150-V | Vertical | 150 | 6 |



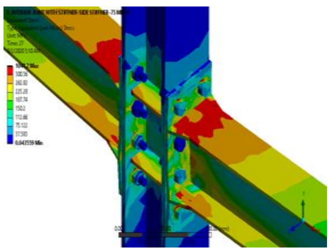
(a)Horizontal side-stiffener



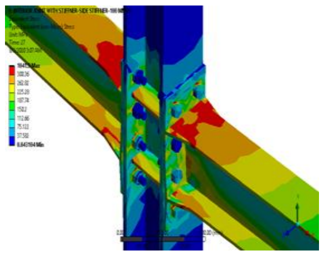
(b) Vertical side-stiffener

**Fig-3** Extended end-plate bolted connections with side stiffeners

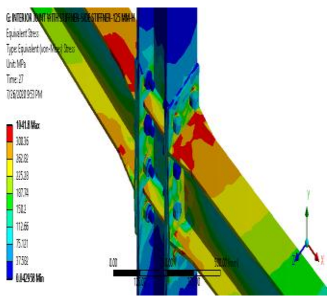
The equivalent stress distribution of extended end-plate bolted connections with horizontal and vertical side stiffeners are shown in Fig 4 (a), (b), (c), (d), (e) and (f) respectively.



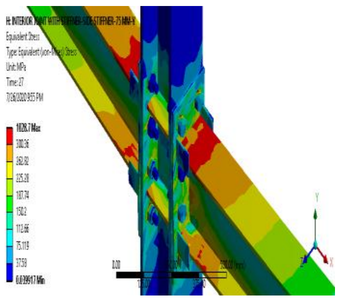
(a) IJ-SS-75-H



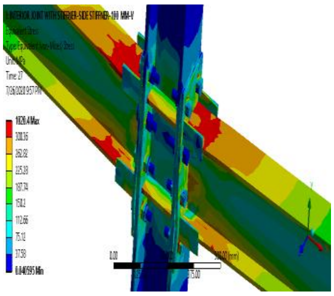
(b) IJ-SS-100-H



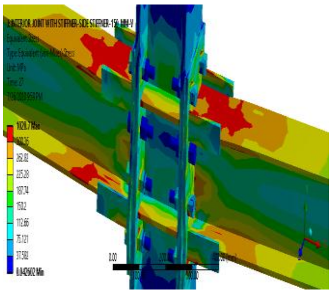
(c) IJ-SS-125-H



(d) IJ-SS-75-V



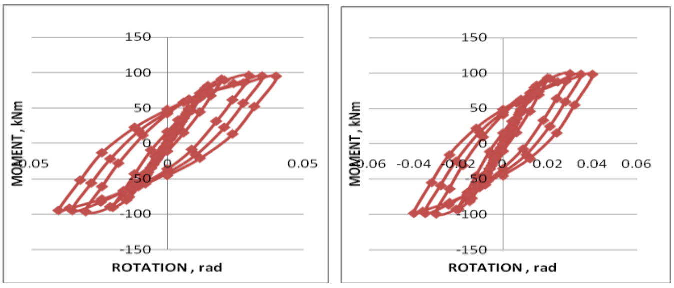
(e) IJ-SS-100-V



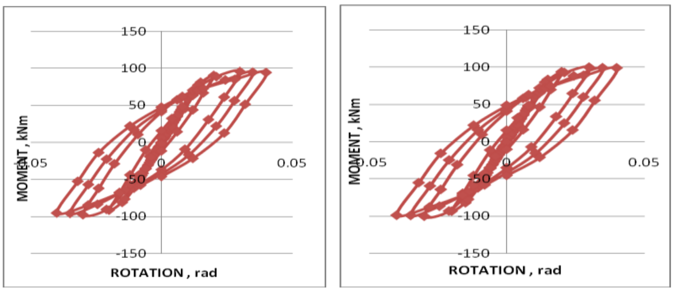
(f) IJ-SS-150-V

**Fig-4** Equivalent stress distribution

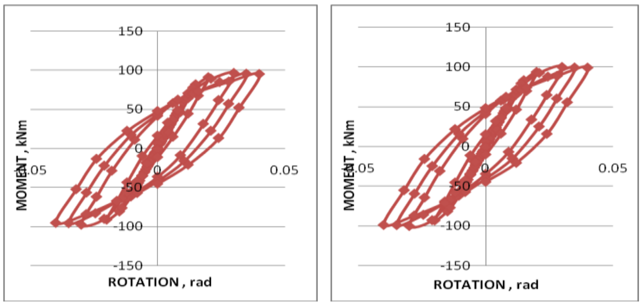
In case of Equivalent stress or Von Mises stress, the stress distribution was observed minimum in column portion and maximum observed at top of the beam flange portion for all the models. The moment-rotation hysteresis loops for left and right side beams for the models are shown in Chart-2.



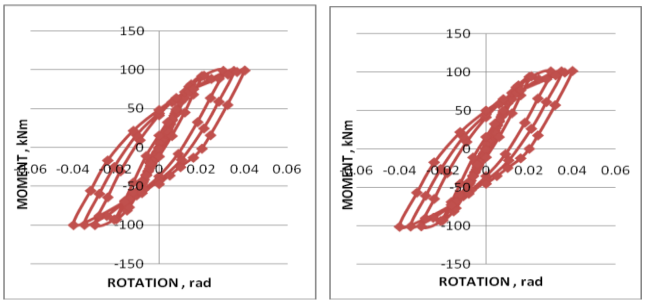

(a) IJ-SS-75-H



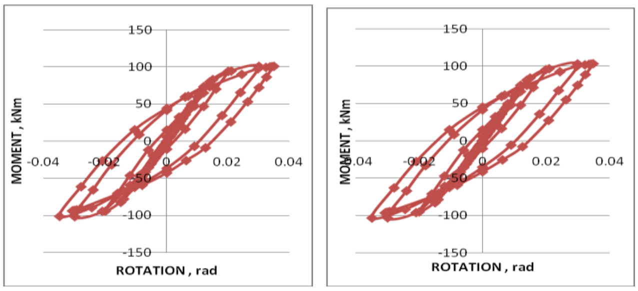

(b) IJ-SS-100-H



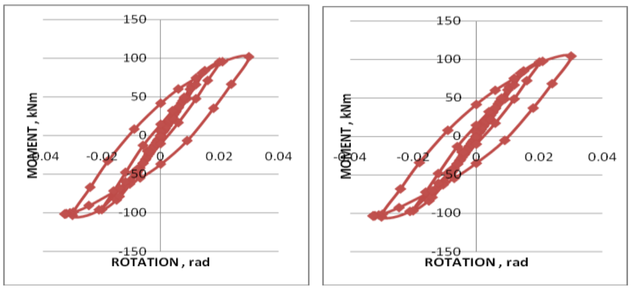

(c) IJ-SS-125-H




(d) IJ-SS-75-V




(e) IJ-SS-100-V




(f) IJ-SS-150-V

**Chart-2** Moment – Rotation hysteresis loops for left and right side beams

In extended end-plate bolted connection with horizontal side stiffeners, Comparing IJ-SS-75-H, IJ-SS-100-H and IJ-SS-125-H with IJ the moment carrying capacity increases with 4%, 4.41% and 5%.

In extended end-plate bolted connection with vertical side stiffeners, Comparing IJ-SS-75-V, IJ-SS-100-V and IJ-SS-150-V with IJ the moment capacity increases with 7.11%, 10% and 15.3%.

## 5. STUDY ON INFLUENCE OF VARYING BEAM HEIGHT INTERIOR JOINT WITH STIFFENER

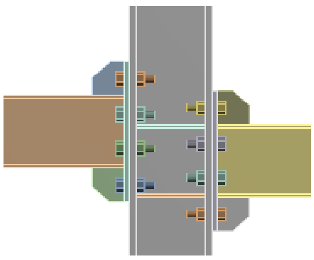
A total of three specimens were modeled. The left side (LS) beam of the joint is same height for all the three models and the right side beam(RS) height is changing without touching the bolts of left side beam. The height of right side beam is changing with respect to, the number of left side beam bolts inside the column web stiffeners. This study is to clarify seismic performance of irregular connection in split-level heights. All interior connection specimens studied are beam height unequal connections and based on the split level height. It is defined according to the height difference between the top of the beams on both sides.

1. VH 80 - beam-interior joint with stiffener (VH 80 beam –IJS)
2. VH 170 - beam-interior joint with stiffener (VH 170 beam –IJS)
3. VH 270 - beam-interior joint with stiffener (VH 270 beam –IJS)

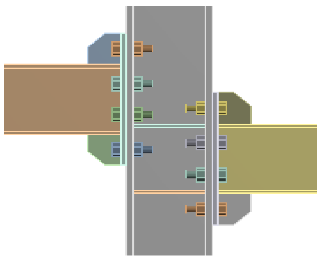
Models were used to analyse the cyclic loading behaviour by studying the equivalent stress distribution, load carrying capacity and moment carrying capacity in bolted beam column connection. The models are shown in Fig 5 and Geometric specifications of models are given in Table 4.

**Table -4:** Geometrical specifications of models

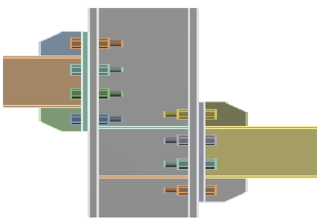
| Models | Height difference (mm) | No. of LS beam bolts inside the column web stiffener |
|---|---|---|
| VH 80 beam –IJS | 80 | 2 |
| VH 170 beam -IJS | 170 | 1 |
| VH 270 beam –IJS | 270 | 0 |



(a)



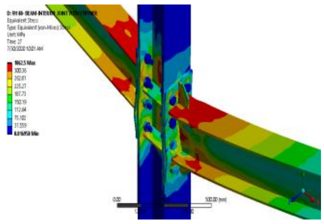
(b)



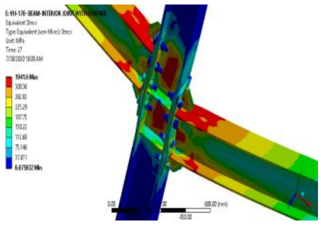
(c)

**Fig-5** Models (a) VH 80 beam –IJS (b) VH 170 beam –IJS (c) VH 270 beam –IJS

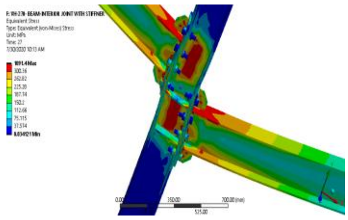
The equivalent stress distribution is shown in Fig 6 and Moment – Rotation hysteresis loops for left and right side beams shown in Chart-3.



(a) VH 80 beam –IJS

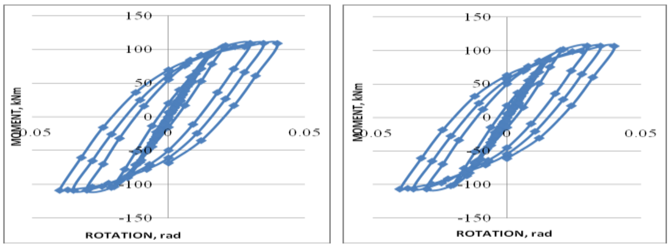


(b) VH 170 beam -IJS

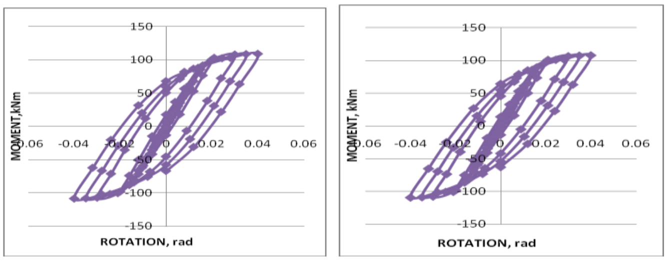


(c) VH 270 beam –IJS

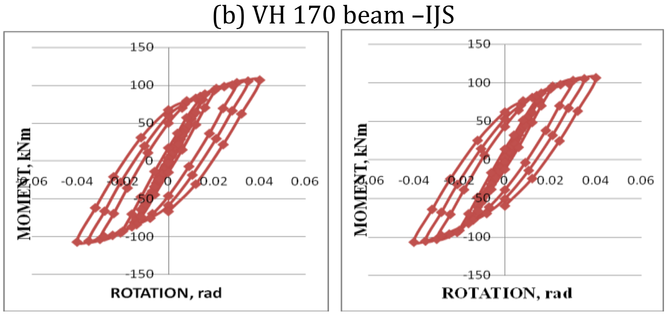
**Fig-6** Equivalent stress distribution




(a) VH 80 beam –IJS




(b) VH 170 beam –IJS




(c) VH 270 beam –IJS

**Chart-3** Moment – Rotation hysteresis loops for left and right side beams

Here the moment carrying capacity of beam-column connections decreases with increase in height difference between the top of the beams from 80mm to 270mm. Comparing VH 80 beam- IJS, VH 170 beam- IJS and VH 270 beam- IJS with IJS 1-1 the load carrying capacity decreases with 1.52%, 1.27% and 2.7% and moment carrying capacity decreases with 1.52%, 1.27% and 2.7%. The stress at panel zone increases with increase in height difference between the top of the beams.

## 6. CONCLUSIONS

The finite element analysis of beam column joints with end-plates was carried out in ANSYS. Interior joint with stiffeners showed better performance when compared with the interior joint without stiffeners. The stiffeners serve the main purpose of increasing the strength and stiffness of the end plate. The stiffeners play a decisive role in semi-rigid connections.

When taking the extended end-plate bolted connection, the connections with end-plate stiffeners shows 13% to 15% more load carrying capacity than unstiffened connection. Therefore a conclusion can be drawn that the end-plate stiffener can increase the stiffness of extended parts of the end plate. Also, due to the endplate stiffener, end-plate deformation is reduced when compared to the unstiffened connections.

With the presence of end-plate stiffeners, the hysteretic behavior, especially moment carrying capacity and rotation capacity, evidently increased. The maximum moment increased by 15% when compared to unstiffened connection. Although there were still gaps between the end plate near the beam tension flange and the column flange, no bending up was found in the outer part of the end plate. This was due to the reduction of prying force by stiffeners.

The connections using horizontal side-stiffeners the load carrying capacity increases with 4% to 5% and in the case of vertical side-stiffeners the load carrying capacity increases with 7% to 15%. Also, the vertical side stiffeners increase the drift ratio and rotation capacity of the connection.

In the varying height beam interior joint, when the height difference between the top of the beams increases drift ratio and deformation capacity of the connection increases, the load carrying and moment carrying capacity decreases from 1% to 3%. This is because the stress at panel zone increases. So we need to study more to strengthen the split-level connection in seismic regions.

## REFERENCES

[1] Keh-chyuan tsai and Egor p. popov, "Cyclic behavior of end-plate moment connections" 1990, J. Struct. Eng, vol.116, pg no: 2917-2930.

[2] Ahmed Ghobarah, Robert M. Korol and Ashraf Osman, "Cyclic behavior of extended end-plate joints" 1992, J. Struct. Eng, vol.118, pg no: 1333-1353.

[3] Emmett A. Sumner and Thomas M. Murray "Behavior of Extended End-Plate Moment Connections Subject to Cyclic Loading" 2002, J. Struct. Eng. vol.128, pg no: 501-508.

[4] Bing Guo, Qiang Gu and Feng Liu "Experimental Behavior of Stiffened an Unstiffened End-Plate Connections under Cyclic Loading" 2006, J. Struct. Eng.vol.132, pg no: 1352-1357.

[5] Shiming Chena and Gang Dub "Influence of initial imperfection on the behaviour of extended bolted end-plate connections for portal frames" 2007, Journal of Constructional Steel Research ,vol.63 , pg no: 211–220.

[6] Elsayed Mashaly, Mohamed El-Heweity ,Hamdy Abou-Elfath and Mohamed Osman, "Behavior of four-bolt extended end-plate connection subjected to lateral loading" 2011, Alexandria Engineering Journal ,vol. 50, pg no: 79–90.

[7] Abdelrahim Khalil Dessouki,Ahmed Hassan Youssef and Mohamed Mostafa Ibrahim "Behavior of I-beam bolted extended end-plate moment connections" 2013, Ain Shams Engineering Journal , vol. 4, pg no: 685–699.

[8] Pu Yang and Matthew R. Eatherton "A phenomenological component-based model to simulate seismic behavior of bolted extended end-plate connections" 2014, Engineering Structures ,vol.75 ,pg no: 11–26

[9] Machel Morrison, Shahriar Quayyum and Tasnim Hassan "Performance enhancement of eight bolt extended end-plate moment connections under simulated seismic loading" 2017, Engineering Structures, vol.151, pg no:444–458.

[10] Machel L. Morrison, Doug Q. Schweizer,Shahriar Quayyum and Tasnim Hassan "An Unstiffened Eight-Bolt Extended End-Plate Moment Connection for Special and Intermediate Moment Frames" 2019, J. Struct. Eng., vol. 145(7): 04019055.

[11] Ashraf ElSabbagh,Tarek Sharaf, Salah Nagy and Mohammed ElGhandour "Behavior of extended end-plate bolted connections subjected to monotonic and cyclic loads" 2019,Engineering Structures , vol.190 pg no: 142–159.