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# COMPUTATIONAL MODELLING OF INDIAN STANDARD EXTENDED ENDPLATE MOMENT CONNECTION

**Prasanna Joshi[1], J G. Solanki[2]**

*[1,2]Structural Department, Veermata Jeejabai Technological Institute, Mumbai,(India)*

## ABSTRACT

*The Endplate moment connections are required in rigid frames for resisting vertical or lateral loads. The moment connections of lateral load resisting frames of the structures in moderate to high seismic zones are very critical and important from stability and seismic energy absorption aspect. The finite element analysis of the joint makes it possible to understand their real behavior at low cost and in a relatively short period of time compared with the experimental tests. This paper presents the analysis of Indian standard steel beam column joint with extended endplate and HSFG bolts using the ABAQUS finite element software. The behavior of the Indian standard steel beam column joint for various endplate configuration with varying endplate thickness and bolt diameter are presented in this paper.*

**Keywords:** ***ABAQUS, Extended Endplate Connection, Finite Element Analysis, HSFG Bolts, Steel Beam-Column Joint.***

## I. INTRODUCTION

Moment connections are designed to transfer bending moments, shear forces and sometimes normal forces. The design strength and stiffness of a moment connection are defined in relation to the strength and stiffness of the connected members. The design strength of a moment connection may be full- strength, that is the moment capacity of the connection is equal to or large than the capacity of the connected member or partial-strength, that is the moment capacity of the connection is less than that of the connected member[1].

Indian standard Extended End-plate moment connections consist of a plate which is welded to the end of a beam that is then field bolted to the connecting member using rows of high strength bolts. An extended end-plate connection has an end-plate that extends above the connecting beam flanges and at least one row of bolts is positioned outside the flanges on the extended part of the end-plate. There are 2 different extended endplate configurations for which the finite element analysis is carried out as shown in Fig.1.1 and Fig.1.2. First configuration as shown in Fig.1.1 consists of 4-Bolt rows and second configuration as shown in Fig.1.2 consists of 5-Bolt rows which are used for the Finite element analysis.

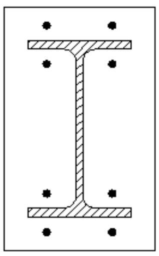

**Fig. 1.1** 4-Bolt Row Extended Endplate connection

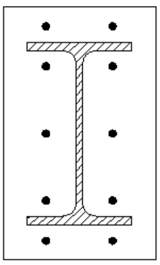

**Fig. 1.2** 5-Bolt Row Extended Endplate connection

## II. ABAQUS MODELLING

In order to gain a thorough understanding of the behavior of bolted extended end plate moment connections, a three-dimensional finite element model was created using ABAQUS[2]. This will allow a thorough examination of the connection to be conducted, without the expensive requirement of materials and resources. The model is designed to study the behavior of the end plate and the bolts when loaded to failure.

### 2.1 Geometry of Model

The model is made in three parts- column, bolts, and beam extruded out from the endplate[3]. Beam and Endplate are modeled as one unit because the purpose of the model is to pay particular attention on the behavior of the endplate and bolts and neglecting the effects of the welds.

### 2.2 Property

In this model all the members are made up of steel (FE250). For each of the materials Young's modulus is defined as 210000Mpa and Poison's ratio as 0.3. The yield and ultimate stress for the bolts were considered as 640Mpa and 800Mpa respectively.

### 2.3 Interaction

The three parts- column, bolts, and beam extruded out from the endplate which were modeled should act as a one unit, so interaction is a major concern in Finite Element software ABAQUS[4]. The friction between the connection components is the essential parameters which define the joint behavior. Small sliding surface to surface contact was applied to all the surfaces which have small relative sliding. The tangential contact between the end plate and the column flange was considered as frictional contact 0.3. Hard contact was considered for the normal contact between the same components. The bolt head / nut were tied constrained to the end plate / column flange.

### 2.4 Discretisation of the model

The mesh refinement must satisfy the need for a fine mesh to give an accurate stress distribution in a reasonable analysis time[5]. The mesh size used was 20mm for all the three parts. All the components of the joints were modeled using the element C3D10 which refers to a 10 node quadratic tetrahedron as shown in Fig.2.1. Fig.2.2 shows the discretized model in ABAQUS.

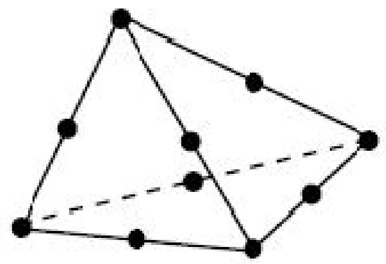

**Fig. 2.1** C3D10-10 Node Quadratic Tetrahedron

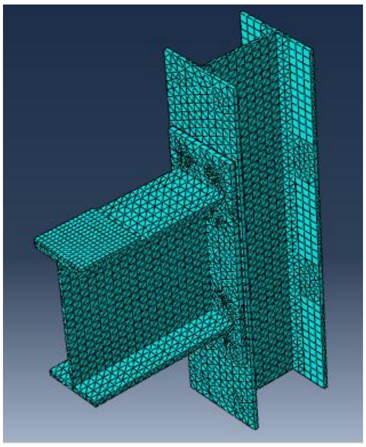

**Fig. 2.2** Meshing of Extended Endplate Moment Connection in ABAQUS

### 2.5 Loading and Boundary condition

Fully fixed boundary conditions were applied at top and bottom of column. This was done in order to fix the model. A plate was modeled on the top of beam flange and uniform pressure was applied on this plate to develop the required moment at the connection.To observe the deflection, a single node was positioned at the end of the beam with the purpose of measuring its deflection in the y-direction.

## III. RESULT INTERPRETATION

Extended endplate configurations shown in Fig.1.1 and Fig. 1.2 were analyzed by varying the component parameters such as the endplate thickness and bolt diameter. Endplate thickness was varied from 12-35 mm and M20 and M24 grade 8.8 bolt diameters were used.

### 3.1 Endplate Thickness Variation for M20 bolt (4-bolt row)

In this case modelling was done using M20 grade 8.8 bolts and varied the endplate thickness from 12-35mm as shown in Fig 3.1. The rotation versus imposed moment plot for the mentioned model is shown in Fig.3.2.

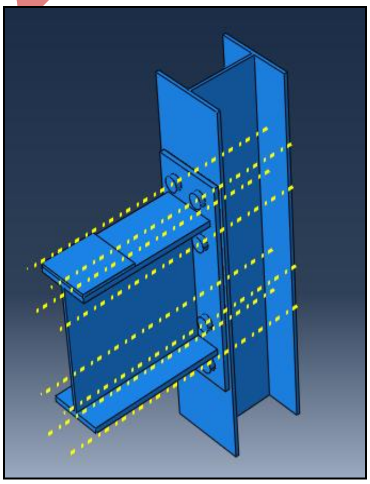

**Fig. 3.1** Extended endplate with 4-Bolt row and M20 bolt

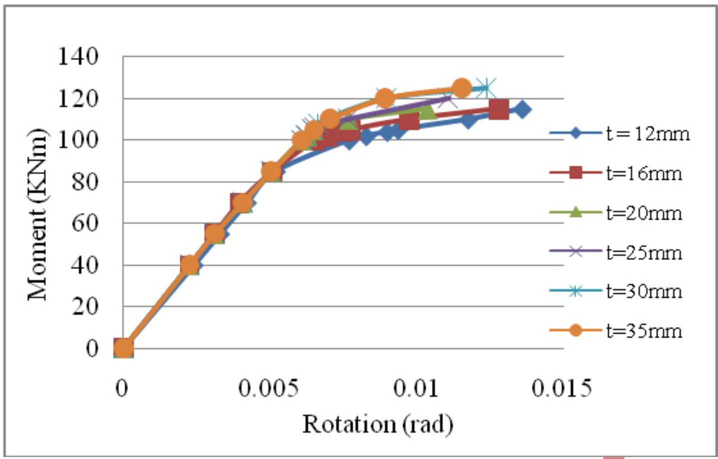


**Fig. 3.2** Moment Rotation curve for varying endplate thickness (M20 bolts)

The yield point is defined as the point at which the linear behavior of the plot ceased. The yield point for various moment rotation curves and the corresponding failure modes are presented in Table 3.1.

**Table 3.1** Yield Points of varying endplate models with M20 bolts (4-bolt row)

| Sr No. | Thickness of plate used in model (mm) | Moment at yield point (KNm) | Failure Plane |
|---|---|---|---|
| 1 | 12 | 85 | Endplate |
| 2 | 16 | 100 | Endplate |
| 3 | 20 | 105 | Column Flange |
| 4 | 25 | 106 | Column Flange |
| 5 | 30 | 108 | Column Flange |
| 6 | 35 | 110 | Column Flange |

For extended end plate configuration with M20 (Grade 8.8) bolts, failure for 12mm and 16mm model occurred through bending of Endplate and for 20mm, 25mm, 30mm , 35mm failure occurred through bending of column flange.

**3.2 Endplate Thickness Variation for M24 bolt (4-bolt row)**

In this case modelling was done using M24 grade 8.8 bolts and varied the endplate thickness from 12-35mm as shown in Fig 3.3. The rotation versus imposed moment plot for the mentioned model is shown in Fig.3.4.

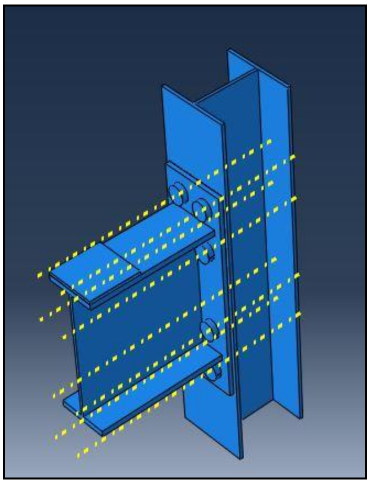

**Fig. 3.3 Extended endplate with 4-Bolt row and M24 bolt**

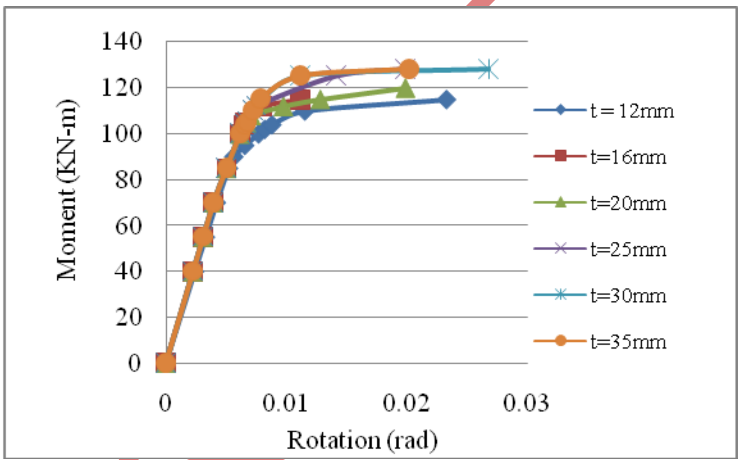


**Fig. 3.4 Moment Rotation curve for varying endplate thickness (M24 bolts)**

The yield point is defined as the point at which the linear behavior of the plot ceased. The yield point for various moment rotation curves and the corresponding failure modes are presented in Table 3.2.

**Table 3.1** Yield Points of varying endplate models with M24 bolts (4-bolt row)

| Sr No. | Thickness of plate used in model (mm) | Moment at yield point (KNm) | Failure Plane |
|---|---|---|---|
| 1 | 12 | 90 | Endplate |
| 2 | 16 | 105 | Column Flange |
| 3 | 20 | 108 | Column Flange |
| 4 | 25 | 110 | Column Flange |
| 5 | 30 | 112 | Column Flange |
| 6 | 35 | 115 | Column Flange |

For extended end plate configuration with M24 (Grade 8.8) bolts, failure for 12mm model occurred through bending of Endplate and for 16mm, 20mm, 25mm, 30mm , 35mm failure occurred through bending of column flange. It was found that increase in diameter of the bolt increases the moment carrying capacity of the connection.

### 3.3 Endplate Thickness Variation for M20 bolt (5-bolt row)

Now in this case modelling was done using M20 grade 8.8 bolts with one extra row of bolt at the centre of Endplate and varied the endplate thickness from 12-35mm as shown in Fig 3.5. The rotation versus imposed moment plot for the mentioned model is shown in Fig.3.6.

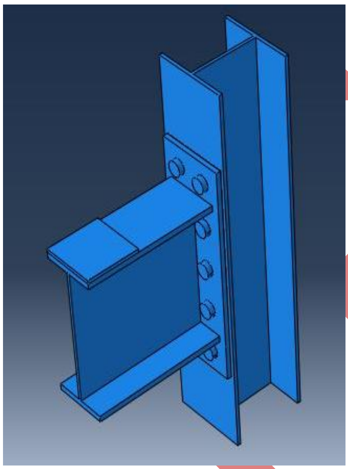

**Fig. 3.5** Extended endplate with 5-Bolt row and M20 bolt

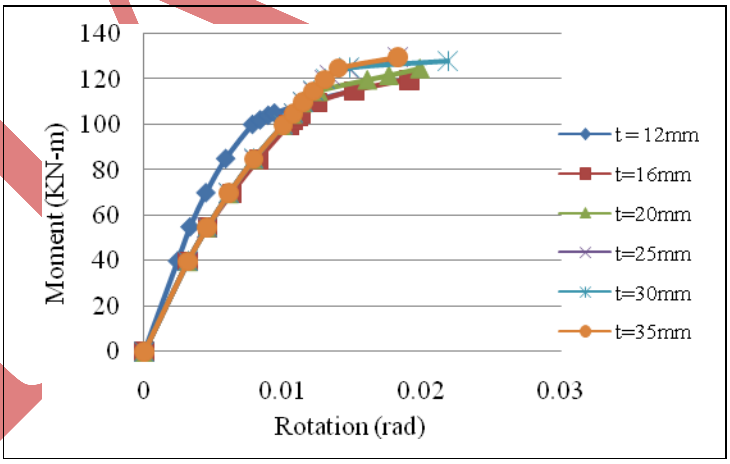


**Fig. 3.6 Moment Rotation curve for varying endplate thickness (M20 bolts)**

The yield point is defined as the point at which the linear behavior of the plot ceased. The yield point for various moment rotation curves and the corresponding failure modes are presented in Table 3.3.

**Table 3.3** Yield Points of varying endplate models with M20 bolts (5-bolt row)

| Sr No. | Thickness of plate used in model (mm) | Moment at yield point (KNm) | Failure Plane |
|---|---|---|---|
| 1 | 12 | 100 | Endplate |
| 2 | 16 | 110 | Column Flange |
| 3 | 20 | 115 | Column Flange |
| 4 | 25 | 120 | Column Flange |
| 5 | 30 | 122 | Column Flange |
| 6 | 35 | 125 | Column Flange |

For extended endplate with one extra row of bolts at centre of endplate, it was observed that yield points were on the higher side as compared to the endplate variation with M24 bolts for the 4 bolt row configuration.

### 3.4 Endplate Thickness Variation for M20 bolt and Column Stiffener (4-bolt row)

Now the column web panel is stiffened by two plates aligned with the beams flanges as shown in Fig. 3.7. The stiffeners are welded to the beam in the support zones. Because the welding is in general not the cause of failure, the column and stiffeners were considered to be one body. The applied moment was plotted against the rotation of the beam for various endplate thicknesses as shown in Fig.3.8.

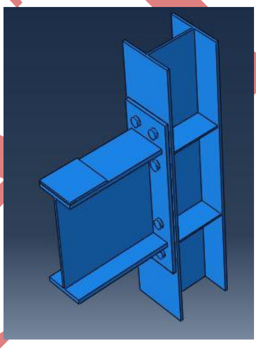

**Fig. 3.7 Extended endplate with 4-Bolt row, M20 bolt and Column stiffener**

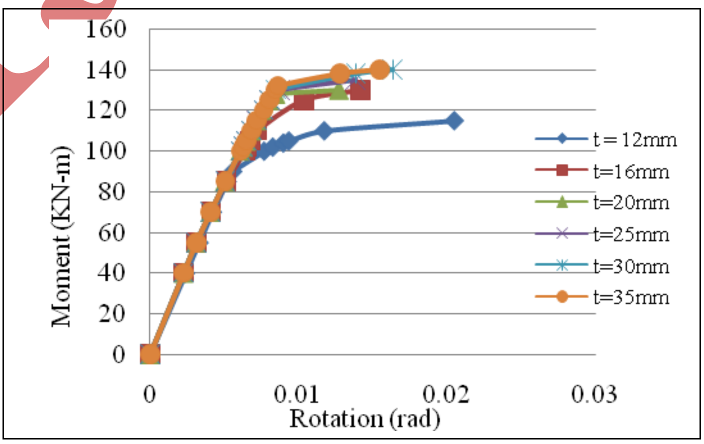


**Fig. 3.8 Moment Rotation curve for varying endplate thickness (M20 bolts)**

The yield point is defined as the point at which the linear behavior of the plot ceased. The yield point for various moment rotation curves and the corresponding failure modes are presented in Table 3.4.

**Table 3.4 Yield Points of varying endplate models with M20 bolts and column stiffener (4-bolt row)**

| Sr No. | Thickness of plate used in model (mm) | Moment at yield point (KNm) | Failure Plane |
|---|---|---|---|
| 1 | 12 | 90 | Endplate |
| 2 | 16 | 110 | Endplate |
| 3 | 20 | 120 | Beam Flange |
| 4 | 25 | 125 | Column Flange |
| 5 | 30 | 130 | Column Flange |
| 6 | 35 | 132 | Column Flange |

For extended endplate with column stiffeners it was observed that failure results obtained were same as that of endplate variation with M20 bolts. With an end plate thickness of 12mm and 16mm failure was found within the endplate. For 20mm model failure was in beam flange and for remaining 25mm, 30mm, 35mm failure occurred through bending of column flange. Analysis showed that yield points were on the higher side as compared to the endplate variation with M20 bolts.

## IV. CONCLUSION

To study the behavior of steel endplate connections, different configurations for the extended endplate connections are studied. Twenty four specimens are modeled using ABAQUS program. The aim of this research is to study the effect of plate thickness, number of bolt rows, bolt diameter and stiffening of column panel zone on the moment resistance and the ultimate rotation of the connection. From the above results following conclusions can be drawn,

1. By increase in the bolt diameter moment carrying capacity of the connection increases as well as failure mode is in the column flange.
2. By increasing the bolt row it was observed that forces in the bolts get reduced which increases the moment carrying capacity of the connection and most of the failure modes are in column flange.
3. By stiffening the column panel zone failure mode is shifted into the beam flange.

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