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Performance of Beam-Column Joint in Steel Frame

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***Abstract*- Steel frames are more preferable than reinforced concrete frames as it takes less time for construction, Due to good quality control, it possesses more sustainability. Long span structural metal frames provide more column free areas. Steel frames are more ductile and flexible in seismic accident than RC frames. The performance of steel frames in vertical and lateral loading is greatly affected by beam-column joint.**

There are different types of steel beam-column connections, rigid, semi-rigid and flexible connections. In this dissertation, rigid end plate connections are considered: Flushed end-plate connections and extended end-plate connections for two types of loadings: AISC loading and IS loading. The design of connections is done by AISC design procedure which is done by EXCEL worksheet. Required sizes for connections are compared for economy. Analysis is done by FEM software to find out rotation at the connection. The moment-curvature relationship for each connection is carried out to find out its exact behavior under the loading. Required quantity of steel is also carried out per connection for comparison for preference of connection-type for particular moment.

***Index Terms*- Flushed end plate, extended end plate, rotation, moment-curvature etc.**

I. INTRODUCTION

Steel frames are more preferable than reinforced concrete frames as it takes less time for construction, also due to good quality control, more sustainability. Long span structural metal frames provides more column free areas. Steel frames are more ductile and flexible in seismic accident than RC frames. The main structural elements of steel framed multi-storey structures have to be conceived as the assemblage of three main structural components , namely, columns, beams and their joints. The capacity of steel frames to resist loads may be determined more by the strength and stiffness of joints than by the properties of the members by themselves. The stiffness and capacity of joints affect the number, location and extent of plastic hinges developing in frame members. This, in turn, determines the distribution local ductility within the frame and influences the overall ductility of the structures. Moment resisting frames: are assemblages of beams and columns, with the beams rigidly connected to the columns. Resistance to lateral forces is provided primarily by rigid-frame action-that is, by the development of bending moment and shear force in the frame members and joints. The Special Moment Resisting Frames (SMRFs) are ductile and deformable structures, and can therefore provide the structural characteristics which are needed for acceptable seismic design. The controlled inelastic deformation of such frames is dominated by the high ductility potential of the beams and the panel zone, so that the corresponding seismic design requirements focus on these elements. Ordinary moment resisting frames (OMRF): is a moment-resisting frame not meeting special detailing requirement for ductile behavior. Efficiency of frames against lateral load mainly depends on quality of beam-column joints in frames

The behavior of the beam-column connections in the multi-storey frame structures (MSFS) is viewed as a whole and it's in direct correlation and dependence with the behavior of their main constructive fundamental elements (steel beams, columns and the elements for their connection). So it is very necessary to design the steel beam-column connection against seismic load and detailed it with ductile detailing.

In this study, comparison of design of connections between AISC and IS specifications and behavioral study of specific beam-column joint is made. Moment-curvature relationship for particular connection is plotted. Cost effective and strength effective connection for particular case by comparison between quantity of steel required and rotation for particular moment is also presented.

II. METHODOLOGY

To study the design of beam-column connections for AISC and IS specification. For that EXCEL worksheets are prepared for particular type of connection for different specifications Quantity of steel required per connection is carried out in kg for comparison for economy.

III. PROBLEM FORMULATIONS

For this study, different Beam-column connections are considered.

1. Four bolted extended end-plate connection (By design guide 16)
2. Four bolted extended end-plate connection (By design guide 4- seismic and wind applications.)
3. Two bolted Flushed end-plate connection

And every connection is analyze for

1. AISC loading specification
2. IS loading specification & designed for AISC design procedure (i.e. by design guide 16 and design guide 4 which is for seismic and wind application design of connection.) Modelled the connection in SOLIDWORKS software and analyzed in FEM for gradual increase in required moments and find out moment-curvature relation of particular joint for its behavior Fixed parameters:

1. Length of the beam considered – 1m
2. Length of column considered – 2m
3. Actual Span of the frame – 5m
4. Spacing of the frames (for loading) – 5m

End-plate connections are considered with specifications as follows.

1. Column = ISHB 300
   Beam = ISMB 200
2. Column = ISHB 350
   Beam = ISMB 250
3. Column = ISHB 450
   Beam = ISMB 300

IV. RESULT AND DISCUSSION

A. Comparison between Moment Curvature Relations of Connections is presented using Beam-ISMB 200 and column – ISHB 300 for various aspects as under:

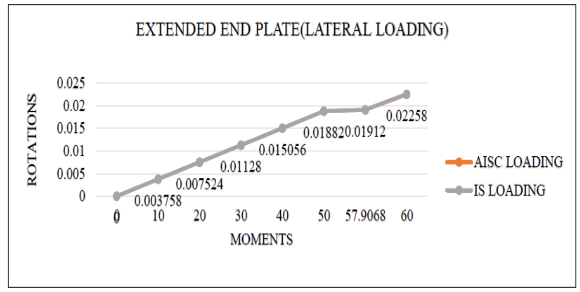

Figure 1 Comparison between Moment curvature relations of extended end-plate for both specification

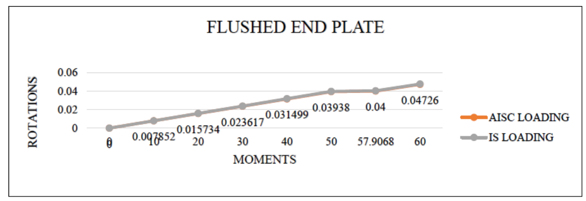

Figure 2 Comparison between Moment curvature relations of Flushed end-plate for both specification

Figure 3 Comparison between Moment curvature relations of extended end-plate (Lateral loading) for both specification

B. Comparison between Moment Curvature Relations of Connections is presented using Beam-ISMB 200 and column – ISHB 300 for various aspects as under:

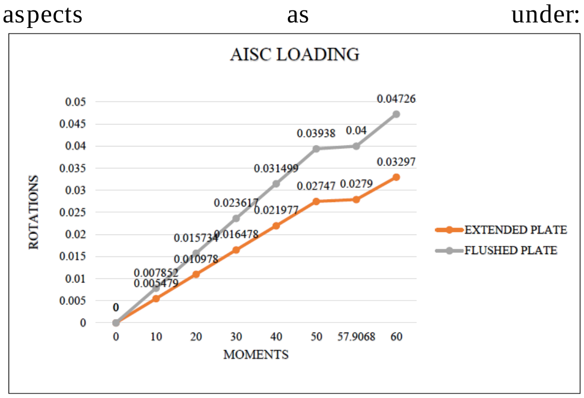

Figure 4 Comparison between Moment curvature relations of AISC specification for extended and

flushed end-plate connections.

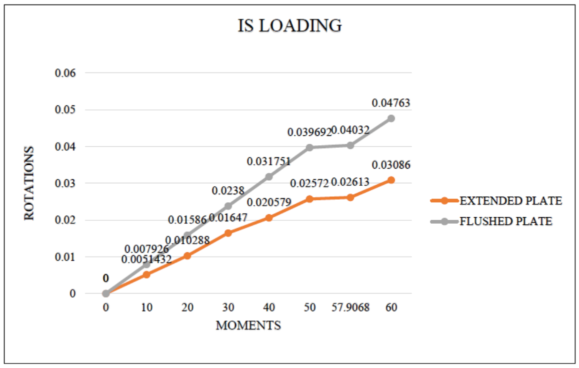

Figure 5 Comparison between Extended end-plate and Flushed end-plate connections for IS specification

C. Comparison between Moment Curvature Relations of Connections is presented using Beam- ISMB 200 and column – ISHB 300 for various aspects as under:

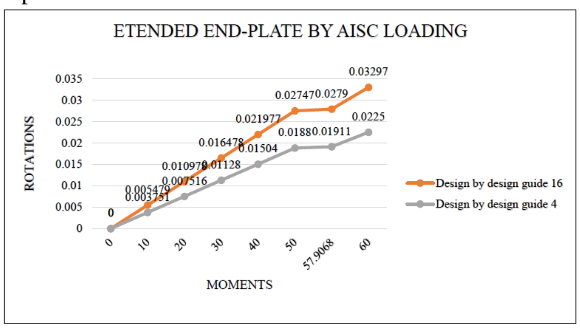

Figure 6 Comparison between Moment rotation curvatures of extended end-plate designed for Lateral loading and Vertical loading.

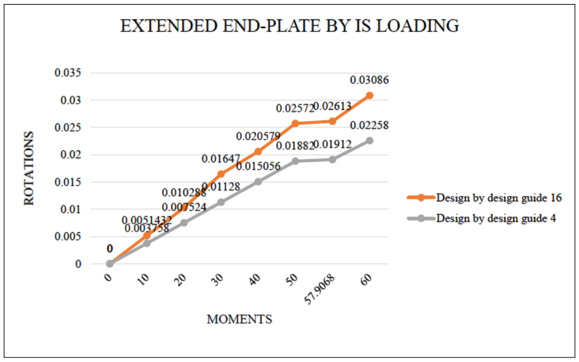

Figure 7 Comparison between Moment rotation relations of extended end-plate designed for Lateral loading and Vertical loading.

D. Comparison between Moment Curvature Relations of Connections is presented using Beam- ISMB 250 and column – ISHB 350 for various aspects as under:

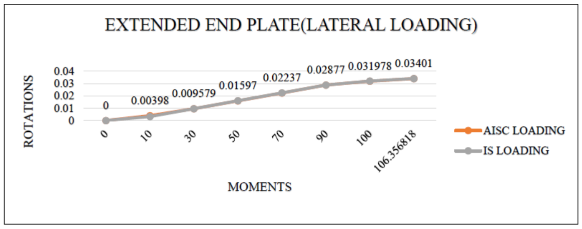

Figure 8 Comparison between moment- curvature relation of AISC and IS specification of Extended end plate connections (Lateral loading)

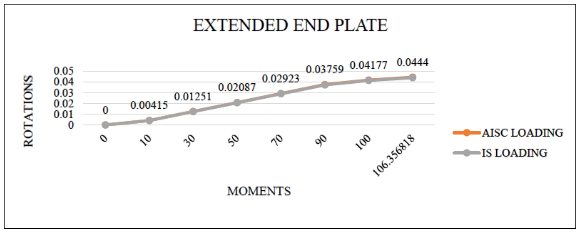

Figure 9 Comparison between Moment- curvature relation of AISC and IS specification of extended end plate-connections

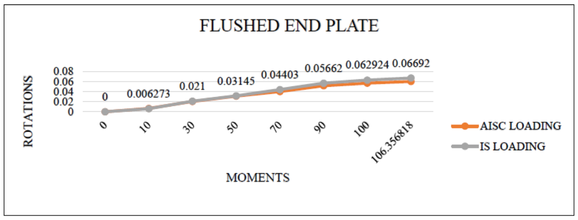

Figure 10 Comparison between Moment- curvature relation of AISC and IS loading of flushed end plate connections

E. Comparison between Moment Curvature Relations of Connections is presented using Beam- ISMB 250 and column – ISHB 350 for various aspects as under:

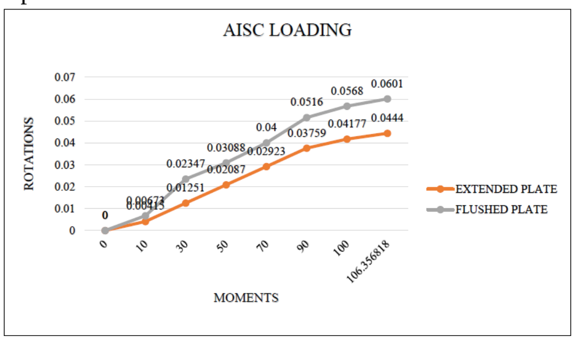

Figure 11 Comparison between Moment curvature relations of AISC specification of extended end-plate

connection and flushed end plate connection

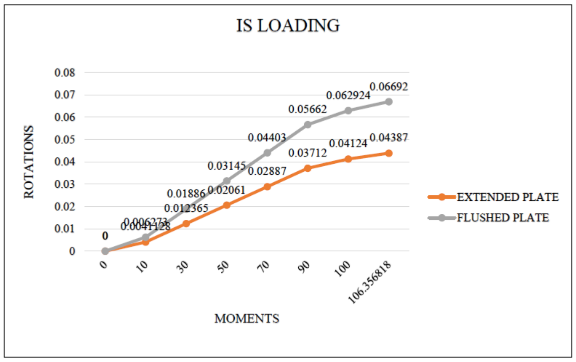

Figure 12 Comparison between moment-curvature relations of IS specification of extended end-plate and flushed end plate connections.

F. Comparison between Moment Curvature Relations of Connections is presented using Beam- ISMB 250 and column – ISHB 350 for various aspects as under:

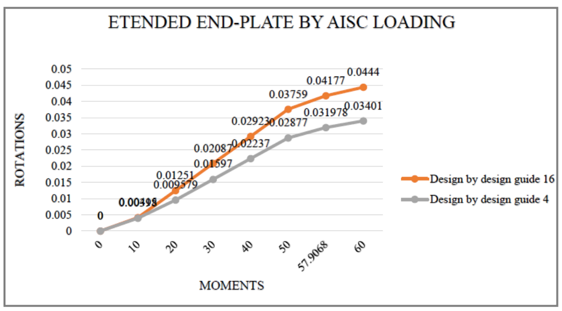

Figure 13 Comparison between moment curvature relations of design for lateral loading and vertical loading of extended end plate connections.

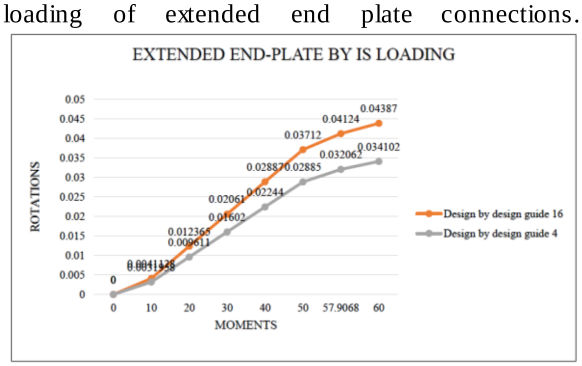

Figure 14 Comparison between moment curvature relations of design for lateral loading and vertical loading of extended end plate connections.

G. Comparison between Moment Curvature Relations of Connections is presented using Beam- ISMB 300 and column – ISHB 450 for various aspects as under:

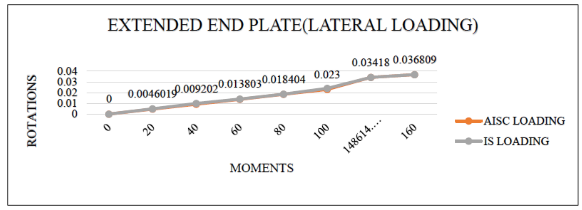

Figure 15 Comparison between moment- curvature relation of AISC and IS specification of Extended end plate connections (Lateral loading)

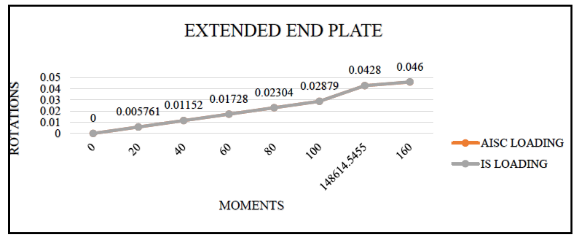

Figure 16 Comparison between Moment- curvature relation of AISC and IS specification of extended end plate connections

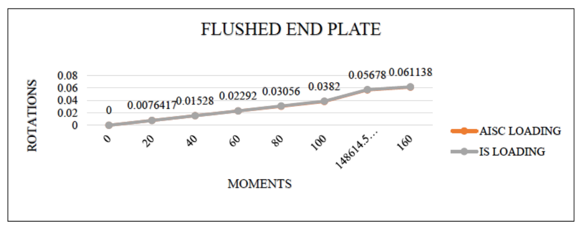

Figure 17Comparison between Moment- curvature relation of AISC and IS specification of flushed end plate connections

H. Comparison between Moment Curvature Relations of Connections is presented using Beam- ISMB 300 and column – ISHB 450 for various aspects as under:

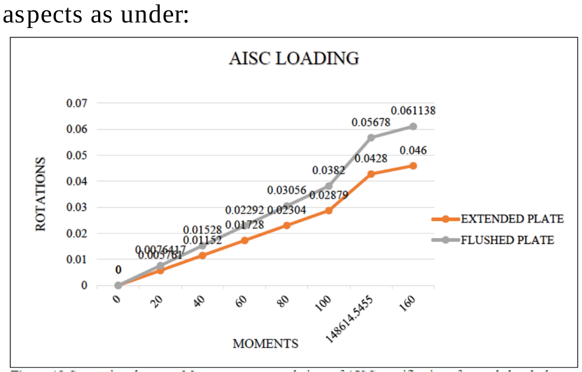

Figure 18 Comparison between Moment curvature relations of AISC specification of extended end-plate connection and flushed end plate connection

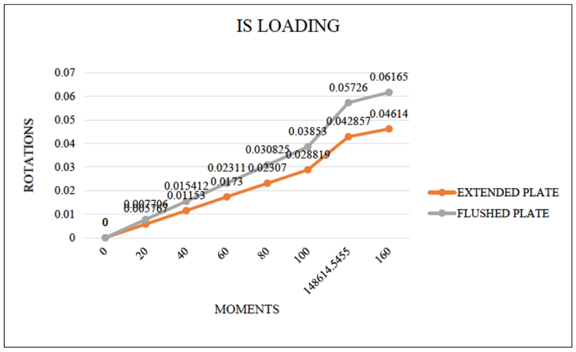

Figure 19 Comparison between moment- curvature relations of IS specification of extended end-plate and flushed end plate connections.

I. Comparison between Moment Curvature Relations of Connections is presented using Beam-ISMB 300 and column – ISHB 450 for various aspects as under:

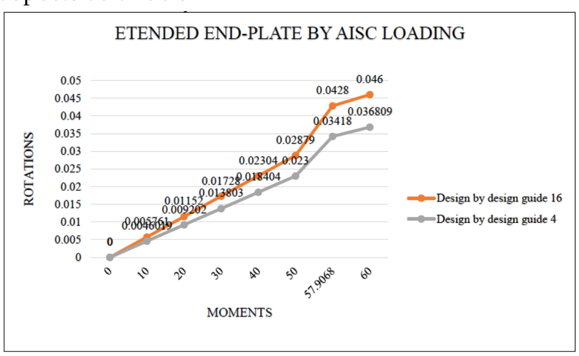

Figure 20 Comparison between moment curvature relations of design for lateral loading and vertical loading of extended end plate connections.

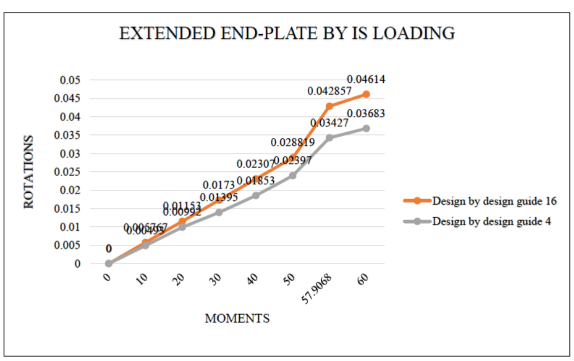

Figure 21 Comparison between moment curvature relations of design for lateral loading and vertical Loading

Table 1 Required sizes of connections

Type →	Flushed end plate		Extended end plate		Extended end plate(Lateral loading)
Loading↓	Thick end plate and smaller diameter of bolt	Thin end plate and larger diameter of bolt	Thick end plate and smaller diameter of bolt	Thin end plate and larger diameter of bolt	Thin end plate and larger diameter of
	Beam – ISMB 200 and Column – ISHB 300				
AISC Loading	t = 28mm	t = 25mm	t = 25mm	t = 22mm	t = 28mm
	Φ = 20mm	Φ = 20mm	Φ = 12mm	Φ = 20mm	Φ = 16mm
IS loading	t = 25mm	t = 22mm	t = 22mm	t = 20mm	t = 32mm
	Φ = 12mm	Φ = 25mm	Φ = 10mm	Φ = 20mm	Φ = 16mm
	Beam – ISMB 250 and Column – ISHB 350				
AISC Loading	t = 36mm	t = 32mm	t = 32mm	t = 28mm	t = 36mm
	Φ = 25mm	Φ = 25mm	Φ = 20mm	Φ = 25mm	Φ = 20mm
IS loading	t = 32mm	t = 28mm	t = 28mm	t = 25mm	t = 40mm
	Φ = 20mm	Φ = 25mm	Φ = 20mm	Φ = 25mm	Φ = 20mm
	Beam – ISMB 300 and Column – ISHB 450				
AISC Loading	t = 40mm	t = 36mm	t = 36mm	t = 30mm	t = 40mm
	Φ = 25mm	Φ = 25mm	Φ = 20mm	Φ = 25mm	Φ = 25mm
IS loading	t = 36mm	t = 36mm	t = 30mm	t = 25mm	t = 40mm
	Φ = 25mm	Φ = 30mm	Φ = 10mm	Φ = 25mm	Φ = 40mm

Table 2 Comparison of steel required per connections:

Type →	Flushed end-plate	Extended end-plate	Extended end-plate (lateral loading)
Beam- ISMB200 and Column – ISHB300			
AISC loading	7.91545kg	7.91545kg	14.7025kg
IS loading	6.2799kg	8.36017kg	16.5865kg
Beam- ISMB250 and Column – ISHB350			
AISC loading	10.58208kg	15.17018kg	21.7184kg
IS loading	11.74145kg	13.52168kg	23.8379kg
Beam- ISMB300 and Column – ISHB450			
AISC loading	16.57365kg	18.09153kg	28.4373kg
IS loading	15.16065kg	15.2659kg	28.4373kg

V. CONCLUSION

Based on the numerous case studies, following conclusions are drawn

1) All rotations in connections are less than 0.04c (IS specification) so are rigid joint and frame is SMRF.
2) According to the design of the connections, in specific combination of beam and column sizes, required thickness of the end-plate and diameter of bolt are greater in case of flushed end-plate connections than extended end-plate connections.
3) For specific loading, there is 19% average increase in quantity of steel in extended end plate than flushed end plate connection.
4) There is 30% average decrease in rotation of extended end plate than flushed end plate
5) In case of extended end plate connection, thickness of end-plate and diameter of bolt are greater in case of design by lateral loading than vertical loading.
6) In case of vertical loading, thickness of end-plate and diameter bolt are greater for AISC loading than

IS loading, while thickness of end-plate and diameter of bolt are smaller in AISC loading than IS loading in lateral loading.

7) There is 30% average decrease in rotation of extended end plate in lateral loading than vertical loading.

8) From the moment curvature relations, the values of rotations in case of any specific connections are same for AISC loading and IS loading

9) Quantity of steel required in IS loading is average 13% less than that of AISC loading for vertical loading in extended end-plate.

10) Quantity of steel required in AISC loading is average 7% less than that of IS loading for lateral loading in extended end-plate.

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