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Effect of Partial Restraint on Moment Resisting Steel Frame

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***Abstract*- In steel buildings, to achieve the economy and construction ease moment resisting frames are used. However these moment connections are complicated from analysis and design point of view. The moment connections are designed for plastic moment i.e. rigid connections. To resist the plastic moment, thicker plate is required. For large scale project there is need to reduce the thickness in order to achieve economy. The fully restraint steel frame is steel frame with 100% restraint of beam to column connection. The partially restraint in frames are introduced in the form of percentage of full restraint. The partial restraints provided are 90%, 80, 70%, 60%, and 50%. The steel frames are analyzed at STAAD Pro software. The analysis results are checked and compared with fully restrainedsteel frame. The beam to column connection will be design for different partially restraint frame. The end pate connection without stiffeners will be used for connection. The end plate will be designed for resulting moment from steel frame analysis.**

***Index Terms*- Steel Frame, Moment Connection, Partial Restraint, End Plate Connection.**

I. INTRODUCTION

Steel building is made up of steel frames consist of steel column and steel beams. The steel columns and steel beams are connected by connection. Columns are connected to pedestals and supported on foundation. The steel sections used for steel building are standard sections or built-up sections. Generally I shaped steel sections are used for column and beams. Steel buildings are used for warehouses, Industrial structures, and office buildings. Most of the steel structural members used in structures have to span great lengths and enclose large three dimensional spaces. Hence connections are necessary to bring about stability of structures under different loads. Thus, connections are essential to create an integral steel structure using plate elements. A structure is only as strong as its weakest link. Unless properly designed, the connections joining the members may be weaker than the members being joined.

II. STEEL CONNECTION.

Rigid connections are capable of transmitting the forces and moments. A rigid connection shall be so designed that its deformation has no significant influence neither on the distribution of internal forces and moments in the structure, or on its overall deformation. These are necessary in sway frames for stability and also contribute in resisting lateral loads. Bolted moment end-plate connections are extensively used as moment-resistant connections in metal buildings and steel portal frame construction. Because of their exceptional moment resistance and ease of erection, moment end-plate connections have become predominant in the metal building industry. There are two general types of moment end-plate connections: flush end-plates, Figure 1, and extended end-plates, Figure 2.

A. Flush End Plate

A flush end-plate is one in which the end-plate does not extend beyond the flanges of the beam section and all rows of bolts are contained within the beam flanges. Flush end-plates may be used with or without stiffeners, which consist of gusset plates welded to both the end-plate and the beam web.

A. Flush End Plate

An extended end-plate connection is one in which the end plate protrudes beyond the flanges of the beam section to allow for the placement of exterior bolts. Extended end-plates may also be used with or without stiffeners which usually consist of a triangular gusset plate welded to both the end-plate extension and the beam tension flange in the plane of the beam web.

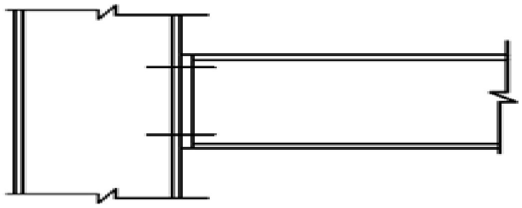

Figure 1: Flush End Plate Connection

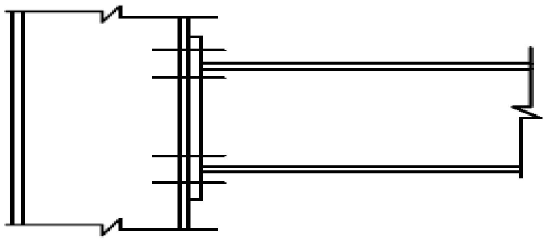

Figure 2: Extended End Plate Connection

III. PARTIALY AND FULLY RESTRAINED STEEL FRAME

A. FULLY RESTRAINED STEEL FRAME

A fully restrained steel frame is in which beam to column connection are fully restrained. The beam transfers the full end moment to column. The moment is transferred through end plate moment connection. The amount of moment transferred to column is represented as 100%. The connection is termed as moment connection. The analysis is complicated. Moment connection becomes uneconomical because of thicker end plate, and diameter of bolts. If bigger building is considered, these moment connections become uneconomical.

B. PARTIAL RESTRAINED STEEL FRAME

A partial restrained steel frame is in which beam to column connection are partially restrained. The beam transfers the partial end moment to column. The moment is transferred through connection. The amount of moment transferred to column is in percentage of full restraint. The connection is termed as partial restrained or semi rigid connection. Partial restrained connections become economical in case of thicker end plate and diameter of bolts because the moment transferred is reduced. The 0% of restrain means simple or shear connections. The percentage of partial restrain considered for analysis are 90%, 80%, 70%, 60% and 50%.

IV. MODELING AND ANALYSIS

Three storied and two bay steel frame is used for analysis. STAAD Pro software will used for analysis of steel frame. The dimensions of frame are bay span = 7.75m and height of first floor 4m and first floor and second floor are 3.5m. The elevation of steel frame is as shown below in figure number 3.

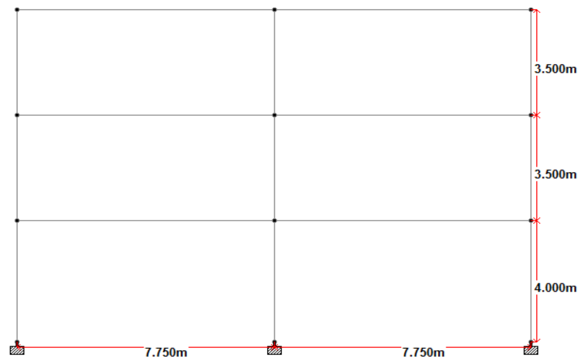

Figure 3: Elevation of Steel Frame

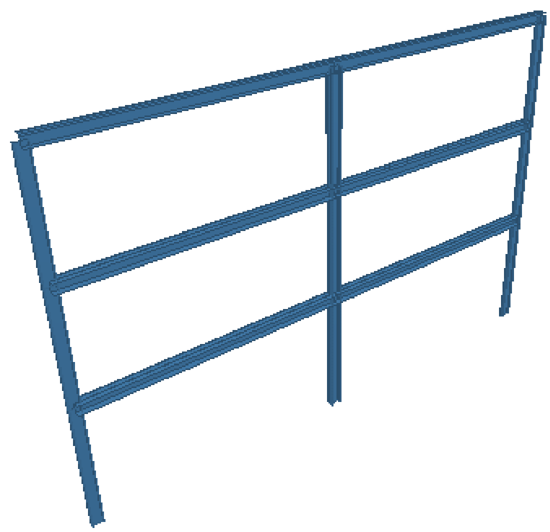

Figure 4: 3D View of Steel Frame

The support conditions for columns are fixed. The vertical loads applied on top floor are 33kN/m and at first and second floor is 48kN/m. The horizontal forces are 8.4kN at top floor and 16.8kN and 18kN at first and second floor respectively. Design code used is AISC 360 ASD. Grade of steel used is A36. For end plate Grade A50 is used and for bolts A307 grade is used.

The results to be obtained from analysis are Horizontal Deflection, Vertical Deflection, Rotation, Axial Force, Shear Force, and Moments.

Models for analysis

Model 1: Steel frame full restrain ie 100% restrain of beam to column connection.

Model 2: Steel frame with 90% restrain of beam to column connection.

Model 3: Steel frame with 80% restrain of beam to column connection.

Model 4: Steel frame with 70% restrain of beam to column connection.

Model 5: Steel frame with 60% restrain of beam to column connection.

Model 6: Steel frame with 50% restrain of beam to column connection.

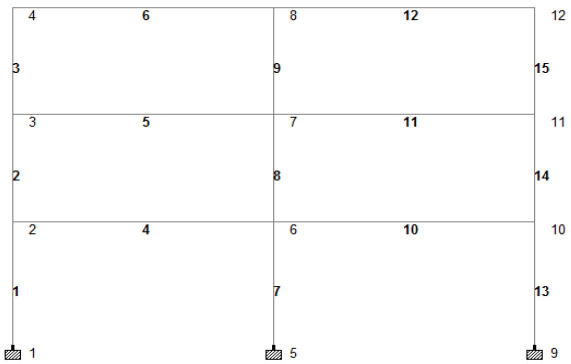

Figure 5: Node and Beam Numbers

Figure 6: Applied Loads

V. RESULTS AND DISSCUSSION

From analysis of six steel frames results are generated as below. The intended parameters of results are provided for each case of partial restraint.The tabulated results are deflection and rtation of nodes and moment, shear force and axial force of members. The analysis done for the frame with overall same dimensions of sections ie for column W10 section is used with different weights and W14 section is used for beams. Thedeeer beam is avoided in office buildings.

Table 1: Analysis results of Model 1

Node/ Member	Node 2	Node 4	Member 4	Member 6
Rotation (mrad)	3.093			
Deflection (mm)		7.863		
Axial Force (kN)			16.47	56.32
Shear Force (kN)			209.86	142.85
Moment (kN-m)			306.67	201.3

Table 2: Analysis results of Model 2

Node/ Member	Node 2	Node 4	Member 4	Member 6
Rotation (mrad)	3.301			
Deflection (mm)		8.669		
Axial Force (kN)			14.47	54.68
Shear Force (kN)			208.43	141.33
Moment (kN-m)			288.47	187.58

Table 3: Analysis results of Model 3

Node/ Member	Node 2	Node 4	Member 4	Member 6
Rotation (mrad)	3.52			
Deflection (mm)		9.957		
Axial Force (kN)			14.145	55
Shear Force (kN)			204.77	138.9
Moment (kN-m)			262.94	170.61

Table 4: Analysis results of Model 4

Node/	Node	Node	Member	Member

Member	2	4	4	6
Rotation (mrad)	3.588			
Deflection (mm)		11.186		
Axial Force (kN)			12.8	53.57
Shear Force (kN)			202.18	137.16
Moment (kN-m)			238.3	154.05

Table 5: Analysis results of Model 5

Node/ Member	Node 2	Node 4	Member 4	Member 6
Rotation (mrad)	3.618			
Deflection (mm)		13.517		
Axial Force (kN)			11.46	51.25
Shear Force (kN)			199	135.58
Moment (kN-m)			210.85	136.91

Table 6: Analysis results of Model 6

Node/ Member	Node 2	Node 4	Member 4	Member 6
Rotation (mrad)	3.765			
Deflection (mm)		15.26		
Axial Force (kN)			8.74	47.4
Shear Force (kN)			197.24	134
Moment (kN-m)			184.22	118.4

Moment Rotation Curve

The graph is plotted for member number 4. The graph is plotted for each case of partial restraint. The graph is plotted between end moment of member and its rotation at that end.

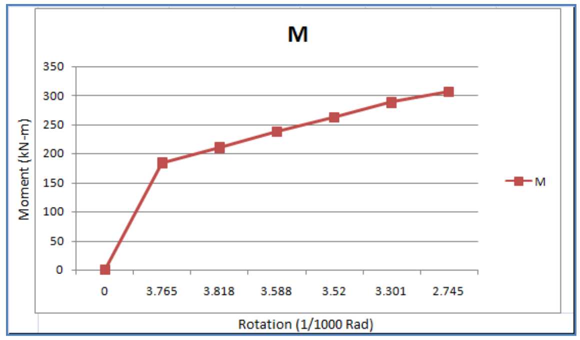

Figure 7: Moment Rotation Curve for Member 4

The graph is plotted between partial restraint and horizontal restraint. The graph is plotted for node node 4. The graph represents the stability of frame with different cases of partial restraints. The horizontal deflection of frame is under the limit provided in code H/200 = 11000/200 = 55mm. The deflections are very less because of heavy loads

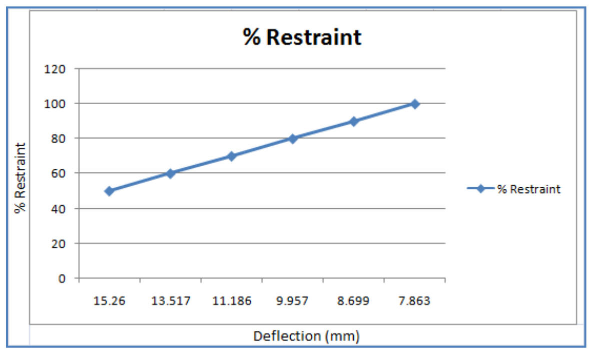

Figure 8: Percentage Restraint to Horizontal deflection for Node 4

Results of quantity of steel required for each case of steel frame with different partial restraints are given below. The results are given for restricted steel sections.

Table 7: Quantity of Steel for Different Partial Restrain

Partial restraint (%)	Steel Quantity (T)
100	8.352
90	8.034
80	7.525
70	7.525
60	7.243
50	7.525

Results of end plate connection design are given for different partial restraints are given below. The results are end plate thickness and bolt diameter required.

Table 8: End Plate Connection Design for Different Partial Restrain (Member Number 4)

Partial Restraint (%)	Diameter of Bolt (mm)	End Plate Thickness (mm)
100	32	45
90	32	45
80	32	45
70	28	40
60	28	40
50	25	36

Table 9: End Plate Connection Design for Different Partial Restrain (Member Number 6)

Partial Restraint (%)	Diameter of Bolt (mm)	End Plate Thickness (mm)
100	28	40
90	25	40
80	25	36
70	25	36
60	22	32
50	22	32

V. CONCLUSION

1. The average increase of deflection due to partial restrain is 1.232mm. The horizontal deflection of frame is under the limit provided in code H/200 = 11000/200 = 55mm. The deflections are very less because of heavy loads on frames.
2. Moment rotation curve shows that the partial restrain increases the rotation of beam. The curve matches the profile shown for flush end plate connection by chen and Lui 1991.
3. Quantity of steel required for frames of different partial restrain shows that increase in partial restrain gives less steel quantity. The minimum Steel quantity is for 60% restrain ie 7.243 Ton.
4. Thickness of end plate decreases with increase in partial restrain. The minimum required thickness is 36mm for 50% restrain at member number 4.
5. The diameter of bolts required also shows decrease in diameter with increase in partial restrain. The minimum diameter of bolt is 25 for 50% restrain at member number 4.
6. The 60% restrain is the optimum case with respective to steel quantity of frame and end plate design both.

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