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The Behavior of Building Structure for Point Displacement: The Use of Moment Resisting Frame of Steel Structure on Beam-Column Connection

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***Abstract:*—Nowadays, multi-storey building use Flush End-Plate and Extended End-Plate. This study aims to compare the bolt beam - column connection to review the behavior of multi-storey building structure with the use of moment resisting frame of steel structure. This study use using Bearing Type Connection Method (in the form of shear loads and bending moments) to generate results of as rotation, translation, and stiffness of two the end plates. In further, the results can be transformed into structural building behavior such as point displacements. The results show that the Flush End-Plate will have greater rotation and translation, but lower stiffness. Thus, the multi-storey building that use Extended End-Plate will have lower rotation and translation but have the greater stiffness. This means the multi-storey building that use Extended End-Plate has a smaller point displacement compare to the Flush End-Plate. The research implication reveals to suggest the structure engineer and designer to objectively to use the types of connections (rigid, Flush End-Plate and Extended End-Plate) that suit to the function, as long as the building is strength, stable and comfort.**

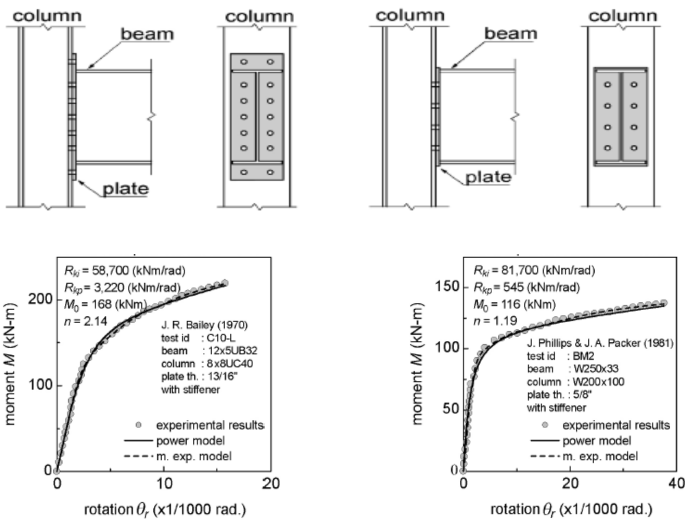
Index Terms:—Beam-Column Connections, Flush End-Plate, Extended End-Plate, Bearing Type Connection Method, Moment Resisting Frame of Steel Structure, Point Displacement.

I. INTRODUCTION

The construction of multi-storey buildings has developed rapidly nowadays, therefore engineers, consultant, analyst, and designer must be able to determine and design which is the most effective and efficient steel structure and connection system. In the initial design of the building structure, the connection is made by Fully Restraint Moment Connection (rigid connection). In contrary, the connection is made by Partially Restraint Moment Connection (semi rigid connection) [1]. Semi-rigid connection produces more stable properties and ductile behavior than rigid connection that resulted a stable earthquake hysteresis behavior [2]. Earthquake forces that transferred from the soil will spread to all building structures and have an impact on the connection and are designed to receive earthquake loads [3].

There are two types of connections that will be analyzed and designed such as Flush End-Plate and Extended End-Plate [4]. Flush End-Plate are connected to column elements, there is no bottom support profile at the base of the beam element. For the Extended End-Plate beam whose end elements are connected to column elements, there is a lower supporting profile at the base of the beam element [4], [5]. So that it will produce differences in the values of rotation, translation, and stiffness in the two different types of bolt joints and have an impact on structural building behavior especially for displacement points [4], [5].

[1] suggest that connections that use flush and extended end-plate are partially connected, they cannot be rigidly perfect, but only produce small angles if the number of bolts is multiplied. As shown in Fig. 1 the differences between Flush End-Plate and Extended End-Plate.



(a) Extended End-Plate *(b) Flush End-Plate*

Fig 1. Comparison between Extended End-Plate with Flush End-Plate
Source: [4]

[6] stated that maximum moment value at beam-column connection for extended end plate is 1.1·M_p. While the maximum moment value of the flush end-plate beam joint is 0.8·M_p. Those connections are depending on the number and diameter of bolts that increases the limitations of placement as proposed by [7]. To stabilize the connection of flush end-plate and extended end-plate, it is suggested to make the number and diameter of the bolts as the parameters [8]. Besides the number, configuration, diameter of bolts, the thickness and material of end-plates are significantly effect on behavioral connection of structural building [9]. [7] argues that the connection has an important role for earthquake response. The results show that of the if the bolts multiply, the connection becomes more rigid but excessive rigidness can cause all forces to the supporting elements which all seismic energy enters the structure and there is no residual energy to the connection [7].

If the material experiences attraction, the connection behavior will results rotation and translation, that can affect building behavior [10]. According to [3] there is no fully restraint connection that is fully rigid because each type of connection has varying flexibility. There are also factors in beam length and column height which cause the structure to be semi rigid [11]. Therefore, each connection has a rotation value. Each connection as a part of structural building, must be designed safety. If so, [12] has stated to limit rotation on the 0.05 rad joint to avoid excessive deformation.

According to the previous study results earlier, the importance of bolts on connections (for Flush End-Plate and Extended End-Plate) will effect on behavior of the structural building especially on point displacement [1], [7], [12]. However, little study shown the comparison between Flush End-Plate and Extended End-Plate to be analyzed further on behavior of the structural building especially on point displacement of multi-storey building.

II. PROCEDURES FOR ANALYSIS

The framework of analysis and design of bolt connections on beam – columns can be explained as follow:

1. Analyze and design the building of momentary steel structures in the ETABS Nonlinear version 9.7.4 program, by entering earthquake load data, rain load, superimposed dead load, and live load. Then to determine dimension of frame section of the structure.
2. The results of ETABS will be shear load, lateral load and moment.
3. Analyze and design the connection of beam-column bolts.
4. The output of bolts analysis (No. 3) will be extension, shift, and stress that occurs on the bolt.
5. Analyze the beam-column bolt connection from the output (No. 4) to get the value of rotation, translation and stiffness.
6. The value of rotation, translation and stiffness (No. 5) will be transformed into ETABS Program to get the value of displacement points.

A. Strong-Column Weak-Beam

This concept is designed so that the column can withstand the bending moment that produced by the beams connected to the column.

$$\frac{\sum M_{pb}}{\sum M_{pc}} < 1 \quad (1)$$

Where,

$\sum M_{pc}$ is the sum the sum of moment at the upper and lower columns of a melting point between beams and columns.

$$\sum M_{pc} = \sum Z_c \cdot \left(F_{yc} - \frac{P_{uc}}{A_g}\right) + V_{col} \cdot \left(\frac{d_{beam}}{2}\right) \quad (2)$$

$\sum M_{pb}$ is the sum of moment on beams at a joint meeting between beams and columns.

$$\sum M_{pb} = \sum \left(1.1 \cdot R_y \cdot F_{yb} \cdot Z_b + V_{beam} \cdot \frac{d_{col}}{2}\right) \quad (3)$$

B. Plastic Modulus Section Properties

- Beam section:

Plastic Modulus about x axis,

$$Z_x = b \cdot t_f \cdot (h - t_f) + t_w \cdot \left(\frac{1}{2} \cdot h - t_f\right)^2 \quad (4)$$

Plastic Modulus about y axis,

$$Z_y = \frac{1}{2} \cdot t_f \cdot b^2 + \frac{1}{4} \cdot t_w^2 \cdot (h - 2 \cdot t_f) \quad (5)$$

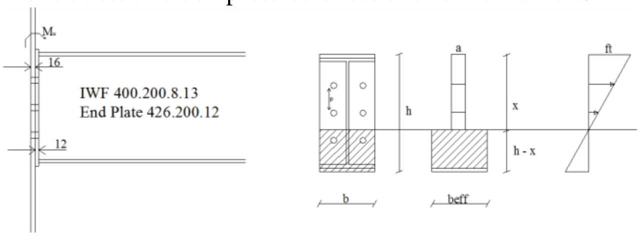
- Column section:

The symmetry of plastic modulus about x axis is equal to y axis,

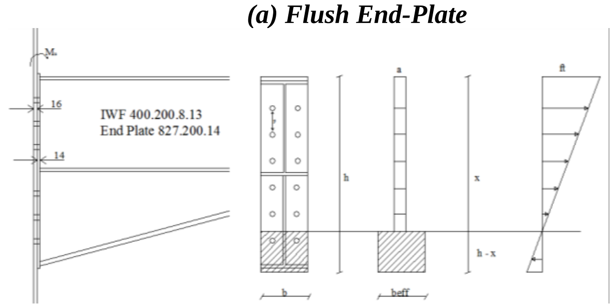
$$Z_x = Z_y = b \cdot t_f \cdot (h - t_f) + t_w \cdot \left(\frac{1}{2} \cdot h - t_f\right)^2 + \frac{1}{2} \cdot t_f \cdot b^2 + \frac{1}{4} \cdot t_w^2 \cdot (h - 2 \cdot t_f) \quad (6)$$

C. Analysis of Bending Moment on Beam-Column Connection

It is necessary to put a neutral cross section line between a connection to find out the cross section that experiences tensile stress and compressive stress due to the moment.



(a) Flush End-Plate



(b) Extended End-Plate

Fig 2. Neutral Cross Section and Stress Diagram

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D. Equivalent Width of Joint Plate

The width of a as the tensile stress area while the effective width of b_{eff} as the compression stress area. With the effective compression stress area about 75%.

$$a = \left(\frac{A_b}{p}\right) \cdot m \tag{7}$$

$$b_{eff} = 0.75 \cdot b \tag{8}$$

Equation squared for neutral lines. Balancing the area of tensile that equal to the area of stress area.

$$(a - b_{eff}) \cdot x^2 + 2 \cdot b_{eff} \cdot h \cdot x - b_{eff} \cdot h^2 = 0 \tag{9}$$

Equation of moment on stress. The total moment of the tensile area and stress area.

$$M_u = \frac{1}{3} \cdot b_{eff} \cdot (h - x)^2 \cdot \sigma_2 + \frac{1}{3} \cdot a \cdot x^2 \cdot \sigma_1 \tag{10}$$

The stress area of compression:

$$\sigma_2 = \frac{h-x}{x} \cdot \sigma_1 \tag{11}$$

The equation substitution (10) and (11)

To get tensile area of compression:

$$\sigma_1 = \frac{3 \cdot x \cdot M_u}{b_{eff} \cdot (h-x)^3 + a \cdot x^3} \tag{12}$$

E. Strain

Based on elastic linear lines on steel.

$$\varepsilon = \frac{\sigma}{E} \tag{13}$$

F. The Connection of Stiffness due to Moments Against Rotation

$$K = \frac{M}{\theta} \text{ (N·mm/rad)} \tag{14}$$

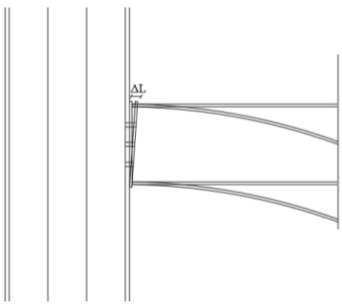
Where,

M is the ultimate moment on the connection obtained from the tensile on the bolt per line multiplied by the distance from centre of the bolt to the neutral axis of the connection.

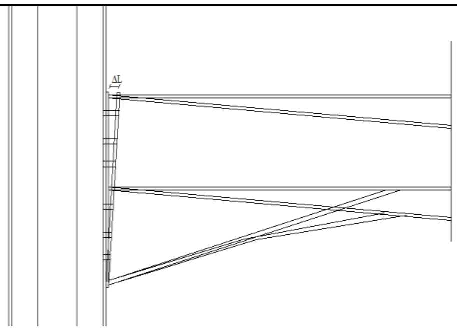
$$T = \sigma \cdot A_b \rightarrow M = T \cdot (x - c) \tag{15}$$

θ is the angle in radians which the elongation of the bolt per row divided by the distance from the centre of bolt to the neutral axis of the joint.

$$\theta = \frac{\Delta L}{(x-c)} \cdot \text{rad} \tag{16}$$



(a) Flush End-Plate



(b) Extended End-Plate

Fig 3. The Stiffness of Connection against Rotation

G. Elongation of Bolts Against Moment

$$\sigma = \frac{T_i}{A},\ \varepsilon = \frac{\Delta L}{L},\ E = \frac{\sigma}{\varepsilon} \rightarrow \Delta L = \frac{T_i \cdot L}{A_b \cdot E} \tag{17}$$

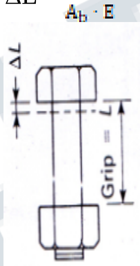


Fig 4. The Elongation of Bolts

H. Analysis of Shear Load on Beam-Column Connection

The existence of shear load (V_u) on a connection resulting simultaneously translation on bolt connection due to configuration of bolt symmetry.

$$f_v = \frac{V_u}{N \cdot A_b} \tag{18}$$

Where,

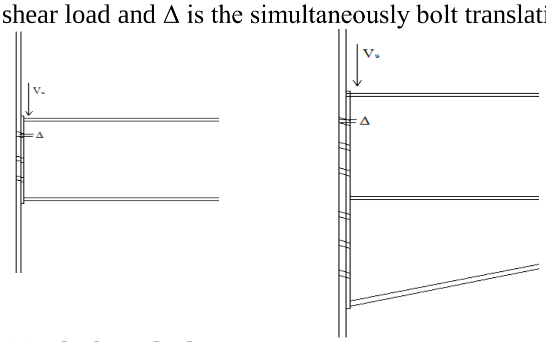
f_v is shear stress, N is number of bolts, A_b is the width of cross section of a bolt.

I. The Connection of Stiffness due to Shear Load Against Translation

$$K = \frac{V}{\Delta} \text{ (N/mm)} \tag{19}$$

Where,

V is shear load and Δ is the simultaneously bolt translation.



(a) Flush End-Plate *(b) Extended End-Plate*

Fig 5. The Stiffness of Connection against Translation

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J. Deformation of Bolts Against Shear Load

$$R = \frac{V}{N} \qquad (20)$$

$$R_{ult} = 0.7 \cdot Fu^{b} \cdot A_{b} \qquad (21)$$

$$R = R_{ult} \cdot \left(1 - e^{-10 \cdot \Delta}\right)^{0.55} \qquad (22)$$

Where,
Minimum requirement of Δ = 8.636 mm
Eccentricity factors, e = 2.718
N is the number of bolts.

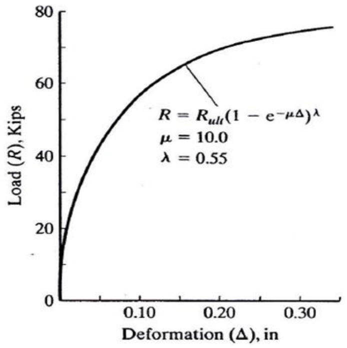


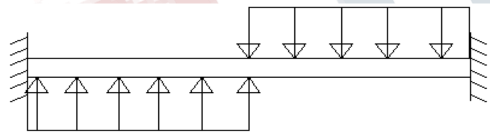
Fig 6. Deformation vs Load of Bolts

K. The Formula of Finite Element Method

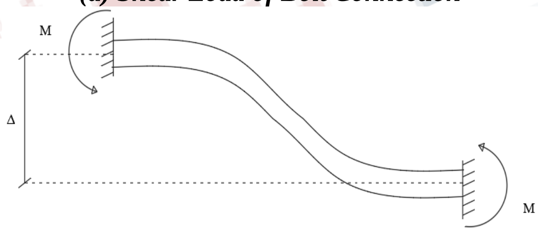
$$\Delta = \frac{P \cdot L^{3}}{n \cdot 12 \cdot E \cdot I} \qquad (23)$$

Where,

Second Moment of Bolt Area, $I_{bolt} = \frac{\pi \cdot d^{4}}{64}$



(a) Shear Load of Bolt Connection



(b) The Simulation of Bolt Translation
Fig 7. Shear Translation of Bolts

L. *The Matrix of Stiffness Joint*

$$K := \begin{pmatrix}
Kg & 0 & 0 & -Kg & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & Km & 0 & 0 & -Km & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \frac{E \cdot A}{L} & 0 & 0 & \frac{-E \cdot A}{L} & 0 & 0 & 0 & 0 \\
-Kg & 0 & 0 & Kg + \frac{12 \cdot E \cdot I}{L^3} & \frac{6 \cdot E \cdot I}{L^2} & 0 & \frac{-12 \cdot E \cdot I}{L^3} & \frac{6 \cdot E \cdot I}{L^2} & 0 & 0 \\
0 & -Km & 0 & \frac{6 \cdot E \cdot I}{L^2} & Km + \frac{4 \cdot E \cdot I}{L} & 0 & \frac{-6 \cdot E \cdot I}{L^2} & \frac{2 \cdot E \cdot I}{L} & 0 & 0 \\
0 & 0 & \frac{-E \cdot A}{L} & 0 & 0 & \frac{E \cdot A}{L} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \frac{-12 \cdot E \cdot I}{L^3} & \frac{-6 \cdot E \cdot I}{L^2} & 0 & Kg + \frac{12 \cdot E \cdot I}{L^3} & \frac{-6 \cdot E \cdot I}{L^2} & -Kg & 0 \\
0 & 0 & 0 & \frac{6 \cdot E \cdot I}{L^2} & \frac{2 \cdot E \cdot I}{L} & 0 & \frac{-6 \cdot E \cdot I}{L^2} & Km + \frac{4 \cdot E \cdot I}{L} & 0 & -Km \\
0 & 0 & 0 & 0 & 0 & 0 & -Kg & 0 & Kg & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -Km & 0 & Km
\end{pmatrix}$$

Notes:
i is the number of beam-element.
K_g is the stiffness of shear spring.
K_m is the stiffness of moment spring.
$\frac{12 \cdot E \cdot I}{L^3}$ is the stiffness of translation.
$\frac{6 \cdot E \cdot I}{L^2}$ is the stiffness of rotation.

III. DESIGN OF STRUCTURAL BUILDING

The beam-column connection will use sample of building with the specifications as follow:
1. The length toward x axis is 30 m then the width toward y axis is 42 m.
2. The distance between column toward x axis is 6 m and the distance between column toward y axis is 6 m.
3. The typical height for each storey is 5 m with the total height of building is equal to 30 m.
4. The use of steel material is BJ-41 with the yield stress, f_y = *250 MPa*. The ultimate stress, f_u = *410 MPa*.
5. The earthquake load is based on the national standard of Indonesia (SNI 1726-2012).
6. The site class is classified as D and the probability of earthquake is 2% in 50 years.
7. Response spectrum with Special Moment Resisting Frame of Steel Structure and ultimate load combination.

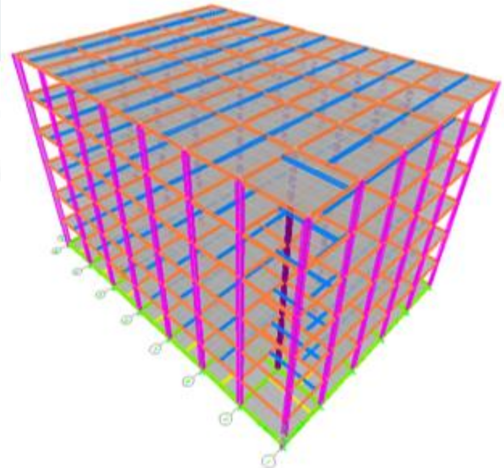


Fig 8. The Sample of Building of Analysis

IV. ANALYSIS AND DESIGN OF BEAM-COLUMN CONNECTION

A. The Behavior of Bolt Connection on Shear Load

The connection of Flush End-Plate for dimension of beam such as 400.200.8.13 and column with dimension of 500.200.10.17. It connects with dimension of end-plate such as 426.200.12. This connection involves 6 bolts with diameter of 20 mm. Hence, the connection of Extended End-Plate for dimension of beam such as 400.200.8.13 and column with dimension of 500.200.10.17. It connects with dimension of end-plate such as 827.200.14. This connection involves 12 bolts with diameter of 20 mm.

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Table 1. Shear Load vs Shear Stress per Bolt

Connection	Flush End-Plate		Extended End-Plate	
Bolt Stress	V (kN)	f_v (N/mm²)	V (kN)	f_v (N/mm²)
Ultimate	107.4	57	107.4	28.5
Yield	753.9	400	1507.9	400
Fracture	1555.1	825	3110.2	825

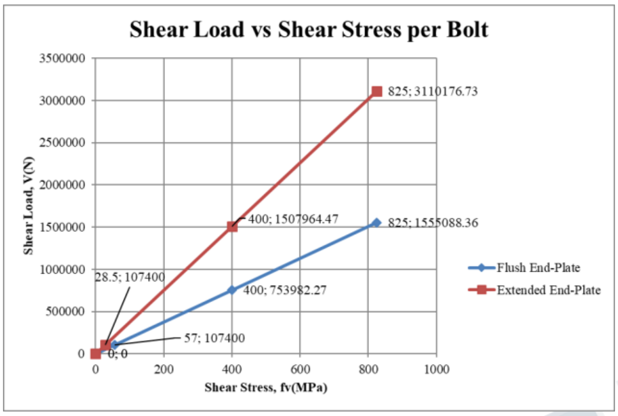

Fig 9. Shear Load vs Shear Stress per Bolt

Based on Fig. 9, shear load on bolt is below the yield stress for Flush End-Plate and Extended End-Plate. Thus, the Extended End-Plate has 50% stronger than Flush End-Plate because Extended End-Plate has twice number of bolts compare to Flush End-Plate.

Table 2. Shear Load vs Translation per Bolt

Connection	Flush End-Plate		Extended End-Plate	
Bolt Translation	V (kN)	Δ (mm)	V (kN)	Δ (mm)
Ultimate	107.4	0.0015	107.4	0.00043
Yield	753.9	0.072	1507.9	0.072
Fracture	1555.1	2.15	3110.2	2.15

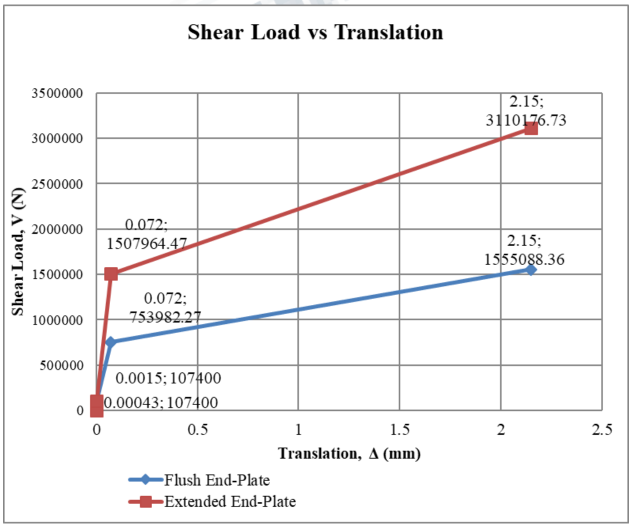

Fig 10. Shear Load vs Translation of Bolt

At the same shear load maximum value toward Flush End-Plate and Extended End-Plate. Table 2 describes that Flush End-Plate has bolt translation 0.0015 mm and Extended End-Plate has bolt translation 0.00043 mm. This means Even though the number of bolts of Extended End-Plate are twice upon Flush End-Plate, but the translation of bolts in Extended End-Plate is 3.49 times less than the flush.

B. The Behavior of Bolt Connection on Moment

Table 3. Stress, Strain and Elongation per Bolt Against Moment of Flush End-Plate

Flush End-Plate					
Bolt Stress	Bolt's line	M (kN·m)	f_t (N/mm²)	ε	ΔL (mm)
Ultimate	1	108.8	91.1	0.00046	0.01275
	2		52.1	0.00026	0.00730
	3		13.2	0.00007	0.00184
Yield	1	477.9	400.0	0.00200	0.05600
	2		228.5	0.00114	0.03199
	3		57.8	0.00029	0.00809
Fracture	1	985.8	825.0	0.00413	0.11550
	2		472.1	0.00236	0.06609
	3		119.2	0.00060	0.01668

Table 4. Stress, Strain and Elongation per Bolt Against Moment of Extended End-Plate

Extended End-Plate					
Bolt Stress	Bolt's Line	M (kN·m)	f_t (N/mm²)	ε	ΔL (mm)
Ultimate	1	108.8	33.3	0.00017	0.00500
	2		26.5	0.00013	0.00398
	3		19.6	0.00010	0.00295
	4		12.8	0.00006	0.00192
	5		6.0	0.00003	0.00090
Yield	1	1307.5	400.0	0.00200	0.06000
	2		318.0	0.00159	0.04769
	3		235.9	0.00118	0.03539
	4		153.9	0.00077	0.02308
	5		71.9	0.00036	0.01078
Fracture	1	2696.6	825.0	0.00413	0.12375
	2		655.8	0.00328	0.09837
	3		486.6	0.00243	0.07299
	4		317.4	0.00159	0.04761
	5		148.2	0.00074	0.02223

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In analyzing connection against moment, the bolts are experiencing tensile. It results the first line of bolts will determine the facture condition of connection. If the first line of bolts were facing fracture condition, the connection is classified as failed connection. Based on Table 3 and Table 4, for Flush End-Plate owns 3 lines of bolt that experiencing tensile because the area is above neutral section. Thus, Extended End-Plate owns 5 lines of bolt that experiencing tensile (the area is above neutral section) but the 6^{th} line has experienced compression because the area is below the neutral section. Hence the analysis will include only 3 lines of bolts in Flush End-Plate and 5 lines of bolts in Extended End-Plate.

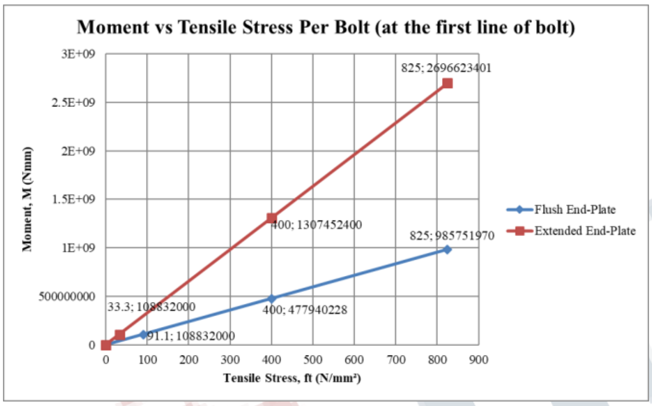

Fig 11. Moment vs Tensile Stress Per Bolt

As explained earlier Extended End-Plate has twice number of bolts compare to Flush End-Plate. The analysis of structural building on connection will resulting the moment of M_u = 108.8 kN·m. For Flush End-Plate, stress bolt on the first bolt line is about f_t = 91 MPa. Meanwhile, for Extended End-Plate, the tensile stress on bolts is smaller 2.7 times than Flush End-Plate (f_t = 33 MPa).

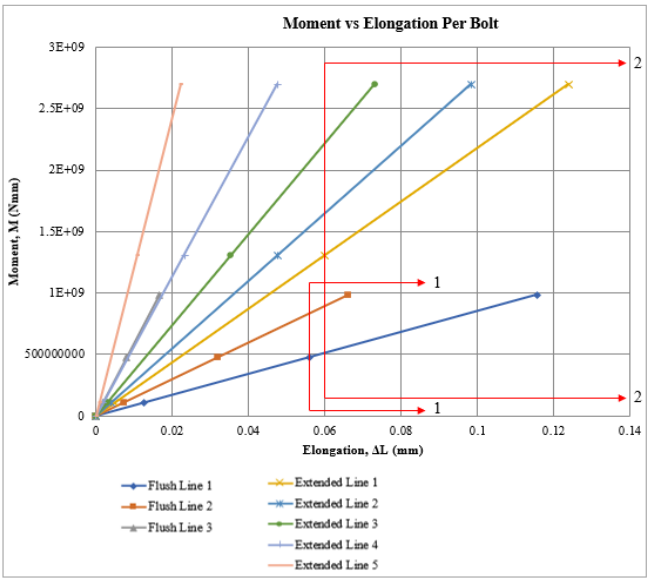

Fig 12. Moment vs Elongation Per Bolt

Furthermore, if the tensile stress (for Flush End-Plate) reach out yield stress (F_y = 400 MPa) then it requires a moment about M_u = 477.9 kN·m. Meanwhile, to reach a yield on bolts, Extended End-Plate requires 2.7 times (M_u = 1307.5 kN·m) compare to a Flush End-Plate.

Therefore, to reach a fracture (F_y = 825 MPa) in Flush End-Plate, it requires a moment (M_u = 985.8 kN·m). Thus, in Extended End-Plate, it requires more than 2.7 times compare to Flush End-Plate with the moment of M_u = 2696.6 kN·m to reach a fracture.

In designing connections, elongation of bolts must below the yield stress. The maximum elongation of yield stress for Flush End-Plate is 0.056 mm and 0.060 mm for Extended End-Plate. Fig. 12 describes the limit of elongation of bolts for Flush End-Plate (as pointed at line 1-1) and for Extended End-Plate is appointed at line 2-2.

In further, both of connections are experiencing the moment of M_u = 108.8 kN·m. The elongation bolts in Flush End-Plate is 0.01275 mm and 0.005 mm for Extended End-Plate. This means Extended End-Plate has shorter elongation bolts about 2.6 times than a Flush End-Plate.

C.The Stiffness of Connection on Rotation

Table 5. The Stiffness of Flush End-Plate on Rotation

Flush End-Plate					
Rotation Bolt	M_u (kN·m)	ΔL (mm)	X (mm)	θ (rad)	K (N·mm/rad)
Ultimate	108.8	0.01275	345.4	0.00037	$2.94 \cdot 10^{11}$
Yield	477.9	0.05600	345.4	0.00160	$2.99 \cdot 10^{11}$
Fracture	985.8	0.11550	345.4	0.00460	$2.14 \cdot 10^{11}$

Table 6. The Stiffness of Extended End-Plate on Rotation

Extended End-Plate					
Rotation Bolt	M_u (kN·m)	ΔL (mm)	X (mm)	θ (rad)	K (N·mm/rad)
Ultimate	108.8	0.00500	680.1	0.00007	$1.47 \cdot 10^{12}$
Yield	1307.5	0.06000	680.1	0.00090	$1.49 \cdot 10^{12}$
Fracture	2696.6	0.12375	680.1	0.00280	$9.63 \cdot 10^{11}$

Due to the twice number of bolts in Extended End-Plate and twice number of area compare to Flush End-Plate, this analysis of stiffness among the end-plates toward rotation will explain further. Table 5 and Table 6 show that the stiffness connection on Extended End-Plate (K = $1.47 \cdot 10^{12}$ N·mm/rad) is more than 5 times compare to the stiffness connection of Flush End-Plate (K = $2.94 \cdot 10^{11}$ N·mm/rad). Even so, the stiffness of connection (on rotation) would not remain to 5 times upon Flush End-Plate, but will decrease to 4.5 times upon Flush End-Plate due to the fracture condition.

Furthermore, the stiffness of connection and radiant are closely related. The higher the radiant, the lower the stiffness of connection. Fig. 13 shows that the radiant of Extended End-Plate is smaller 5 times than Flush End-Plate.

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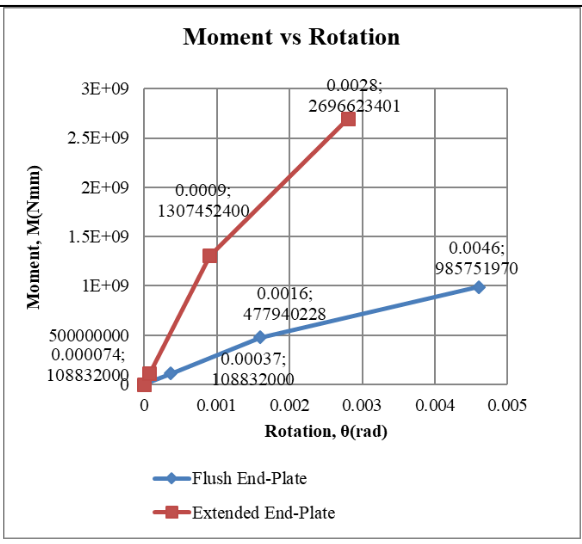

Fig 13. Moment vs Rotation

D. The Stiffness of Connection on Translation

Table 7. The Stiffness of Flush End-Plate on Translation

Connection	Flush End-Plate		
Translation Bolt	V (kN)	Δ (mm)	K (N/mm)
Ultimate	107.4	0.0015	$7.16 \cdot 10^7$
Yield	753.9	0.072	$1.05 \cdot 10^7$
Fracture	1555.1	2.15	$7.23 \cdot 10^5$

Table 8. The Stiffness of Extended End-Plate on Translation

Connection	Extended End-Plate		
Translation Bolt	V (kN)	Δ (mm)	K (N/mm)
Ultimate	107.4	0.00043	$2.50 \cdot 10^8$
Yield	1507.9	0.072	$2.09 \cdot 10^7$
Fracture	3110.2	2.15	$1.45 \cdot 10^6$

Based on previous discussion (twice number of bolts in Extended End-Plate and so on), Table 7 and Table 8 show that the stiffness of connection upon translation in Extended End-Plate ($K = 2.50 \cdot 10^8$ N/mm) is more than 3.5 times compare to the stiffness connection of Flush End-Plate ($K = 7.16 \cdot 10^7$ N/mm). In further analysis of bolts in yield to fracture condition, the stiffness connection will not remain 3.5 times upon Flush End-Plate but decreases to 2 times only.

V. THE BEHAVIOR OF BUILDING STRUCTURE FOR POINT DISPLACEMENT ON SEMI RIGID CONNECTION

To answer research objectives, the current analysis is to define the behavior of building structure especially point of displacement based on the two perspectives such as rigid connection and semi-rigid connection. The semi-rigid connection involves the Flush End-Plate and Extended End-Plate. Table 9, Fig. 14, and Fig. 15 show the results of the analysis of rigid connection, semi-rigid connection (Flush End-Plate vs Extended End-Plate) on building structure especially on point displacement.

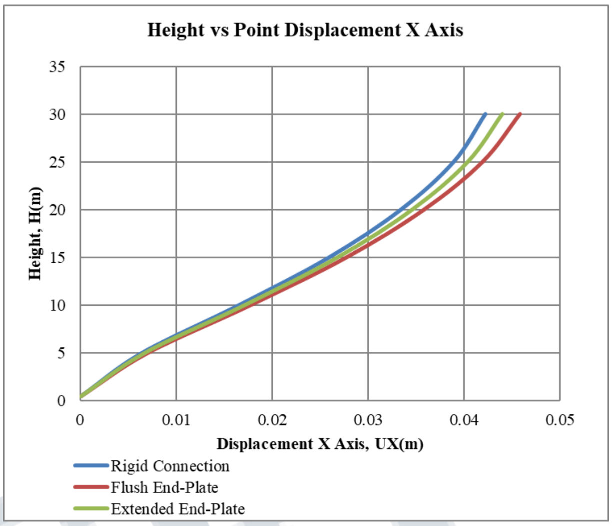

Fig 14. Point Displacement X Axis

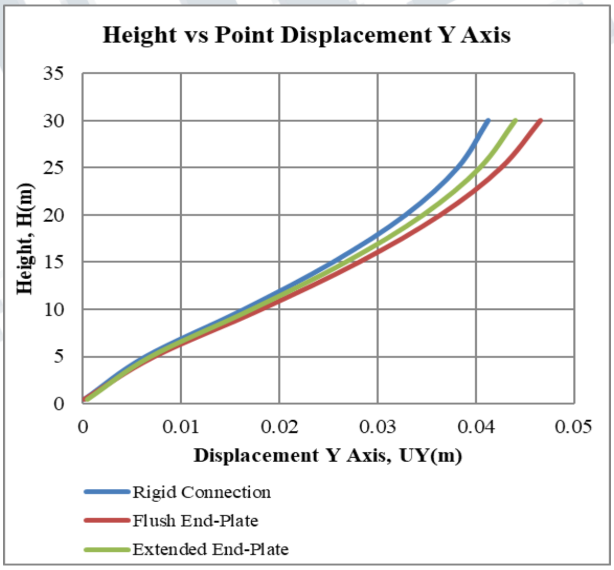

Fig 15. Point Displacement Y Axis

Table 9. Point Displacement

Elevation	Fully Rigid		Semi Rigid			
			Extended End-Plate		Flush End-Plate	
H (m)	UX (mm)	UY (mm)	UX (mm)	UY (mm)	UX (mm)	UY (mm)
30	42.2	41.2	44.0	44.0	45.8	46.6
25	38.9	38.1	40.4	40.4	41.9	42.6
20	33.4	32.8	34.6	34.6	35.8	36.4
15	25.9	25.4	26.8	26.7	27.7	28.1
10	16.5	16.3	17.1	17.1	17.7	18.1
5	6.4	6.3	6.7	6.8	7.0	7.2
0.5	0.1	0.1	0.1	0.4	0.1	0.1

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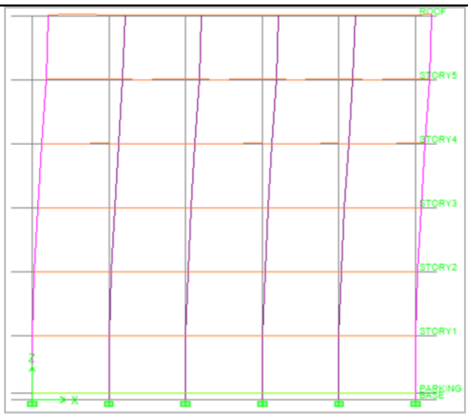
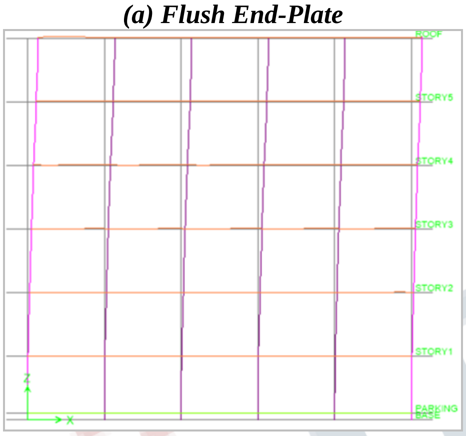
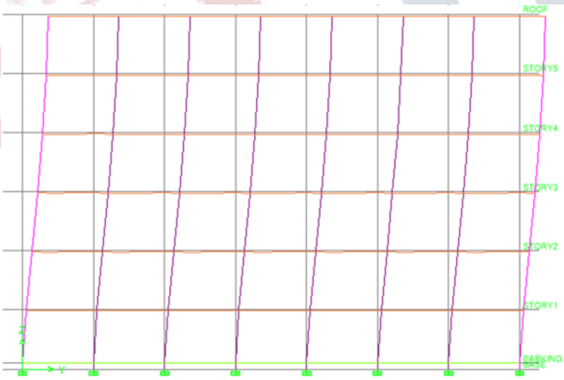


(a) Flush End-Plate

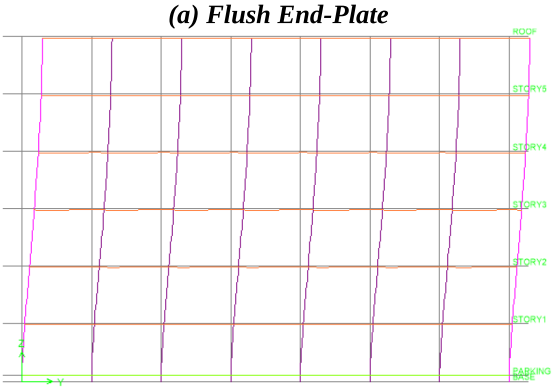


(b) Extended End-Plate

Fig 16. Displacement X Axis (ETABS v.9.7.4)



(a) Flush End-Plate



(b) Extended End-Plate

Fig 17. Displacement Y Axis (ETABS v.9.7.4)

This current analysis only determines the structural building at the top roof of the building (30 m). As shown in Fig. 14 and Fig. 15, when the quake load at x axis, the rigid connection has displacement of 42.2 mm. Then the extended end-plate has 1.8 mm over rigid connection (44 mm). Therefore, the flush end-plate has 1.8 mm over extended end-plate (45.8 mm).

Moreover, when the quake load is at y axis, the rigid connection has displacement of 41.2 mm. Then the extended end-plate has 2.8 mm over rigid connection (44 mm). Therefore, the flush end-plate has 2.6 mm over extended end-plate (46.6 mm).

Thus, Fig. 16 and Fig. 17 show the results of displacement simulation at one section of the current sample (Fig. 8) on quake loads X axis (Fig. 14) and Y axis (Fig. 15) using ETABS version 9.7.4 program.

VI. CONCLUSION

The current research analyzes the behavior of structural building especially on point displacement upon two types of connections (rigid and semi-rigid). The semi-rigid connection involves Flush End-Plate and Extended End-Plate. As the conclusion, when the quake load is at X axis, the Extended End-Plate has more than 3% of displacement than the rigid connection. Hence, at X axis of quake load, the Flush End-Plate has more than 3% of displacement than the Extended End-Plate. Moreover, when the quake load is at Y axis, the Extended End-Plate has more than 6% of displacement than the rigid connection. Hence, at Y axis of quake load, the Flush End-Plate has more than 6% of displacement than the Extended End-Plate.

The use of Flush End-Plate and Extended End-Plate are eligible depends on their function of a building. Flush End-Plate that has bigger deformation will suit to the building that has lower moment ultimate and lower shear ultimate compare to Extended End-Plate connection.

If the building were use Extended End-Plate, then the number of bolts and area of end-plates will be increase. This will lead to the increasing number of moment capacity and share capacity on joints. Therefore, the stiffness will be increase as well. In other words, it can reduce displacement at certain building to make it more comfortable for its users.

REFERENCES

[1] M. Md., Tahir, A. Sulaiman and A. "Sagaff, Structural Behaviour of Trapezoidal Web Profiled Steel Beam Section using Partial Strength Connection" Electronic Journal of Structural Engineering (8) 2008 (2008).

[2] A. S., Elnashai, and A. Y. Elghazouli. "Seismic Resistance of Semi-Rigid Steel Frames." IABSE REPORTS (1996): 127-136.

[3] Mehrabian, Ali. "Seismic performance of steel frames with a post-Northridge connection." (2002).

[4] Kishi, N., M. Komuro, and W. F. Chen. "Four-parameter power model for M-θr curves of end-plate connections." ECCS/AISC workshop connections in steel structures V: Innovative steel connections. 2004.

[5] da Silva, Luís Simões, and Luís Borges. "A probabilistic evaluation of the rotation capacity of end-plate beam-to-column steel joints." (2004).

[6] Sumner, Emmett Ashworth. "Unified design of extended end-plate moment connections subject to cyclic loading." PhD diss., Virginia Tech, 2003.

[7] Babu, Shemy S., and S. Sreekumar. "A study on the ductility of bolted beam-column connections." International Journal of Modern Engineering Research (IJMER) 2.5 (2012): 3517-3521.

[8] Swanson, James A., and Roberto T. Leon. "Bolted steel connections: tests on T-stub components." Journal of Structural Engineering 126.1 (2000): 50-56.

[9] Katula, Levente. "Bolted end-plate joints for crane brackets and beam-to-beam connections." (2007).

[10] Beg, Darko, Erik Zupančič, and Ioannis Vayas. "On the rotation capacity of moment connections." Journal of Constructional Steel Research 60.3-5 (2004): 601-620.

[11] Geschwindner, LOUIS F., and ROBERT O. Disque. "Flexible moment connections for unbraced frames subject to lateral forces-a return to simplicity." ENGINEERING JOURNAL-AMERICAN INSTITUTE OF STEEL CONSTRUCTION 42.2 (2005): 99.

[12] Anwer, Bayan, Sariffuddin Saad, and Hanim Osman. "Structural performance of bolted moment connections among single cold-formed channel sections." International Journal of Engineering and Technology 2.4 (2012): 599-607.