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Modification of Moment Connection of I-Beam to Double-I Built-Up Column by Reinforcing Column Cover Plate

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Abstract

Traditional moment connections of I-beam to double-I built-up column have some problems. They are the stress concentration, brittle fracture of the welds and semi-rigid behavior of the connection. To upgrade the connection behavior, it is proposed to replace parts of the column cover plate, situated in critical areas where the beam flanges (or flange plates) connect to the column cover plate, by thicker and larger plates. To investigate the cyclic behavior of the proposed connection, a series of nonlinear finite element analysis were carried out on different models. Results indicate that the modified connection has such a strength and ductility that can be used in special moment frames. Its stiffness is also in the range of a fully restrained connection.

Keywords: Double-I Built-up Column; Column Cover Plate; Fully Restrained Connection; Special Moment Frame; Reinforced Cover Plate

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1. INTRODUCTION

Double-I built-up sections are extensively used as column sections in moment resisting frames. A double-I built-up section is composed of two I-rolled shapes connected to each other, with a specific distance, by means of the continuous cover plates. The cover plates are fillet welded along their longitudinal edges to the I-shapes. The traditional moment connection of I-beam to the double-I built-up column is shown in Figure 1. In this type of connection, the beam moments transfer to the column through the top and bottom flange plates. These plates are fillet welded to the beam flanges. Top and bottom flange plates are connected through complete joint penetration (CJP) groove welds to the column cover plates. A shear tab is fillet welded to the beam web and column cover plate.

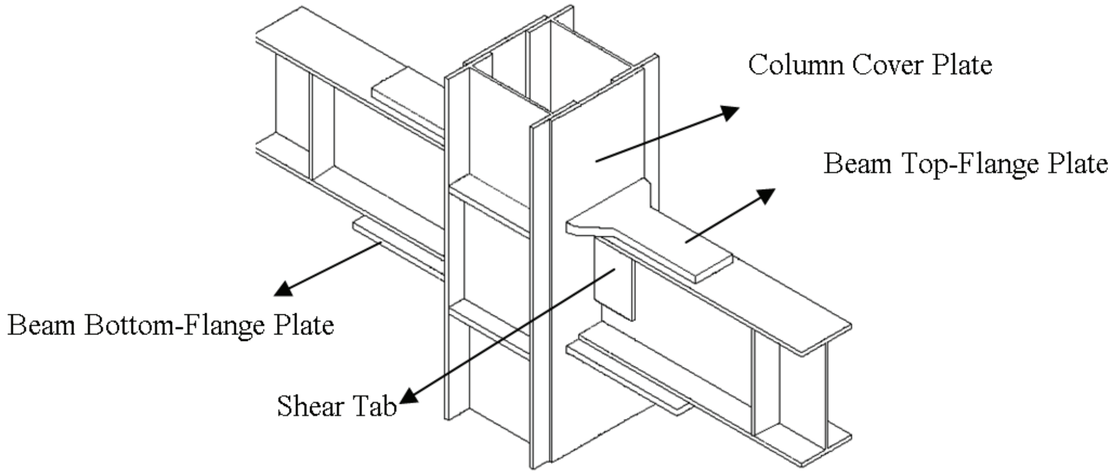


Figure 1: Traditional moment connection of I-beam to double-I built-up column.

The traditional moment connections of I-beam to double-I built-up column have different problems; they have the problem of stress concentration and brittle fracture of the welds and they behave in a semi-rigid manner. Brittle behavior concerns majority of the moment connections in which beam flanges (or beam flange plates) are connected to the column using complete joint penetration (CJP) groove weld (FEMA-355D 2000). This weld produces three-axial stress concentration in joint area and leads to a brittle failure mode which can result in significant loss of strength and ductility. The other problem means semi-rigid behavior, is caused due to column cover plate flexibility. The column cover plate is just welded at its longitudinal edges, so it doesn't provide sufficient stiffness against out of plane deformation. The tensile forces transmitted by the connected beam flange (or flange plate) load the column cover plate as a simply supported beam and cause it to deflect slightly. As this deflection takes place during the load-transferring process it results in significant beam-to-column rotation and semi-rigid behavior of connection. On the other hand the out of plane deflection of column cover plate, considerably increases the stresses in the weld connecting this plate to the I-shaped sections of the column. This stress concentration finally causes premature fracture in the fillet weld of the column cover plate.

In order to upgrade the connection behavior, there are some methods such as; a) using slot and plug welds between the cover plate and the column flanges, b) applying external stiffeners at beam-to-column joints (Mazrooe et al. 2009), c) using internal stiffeners (Iranian National Building Code 2008), d) using side plates (Deylami and Shiravand 2005; Deylami and Yakhchalian 2007; and Deylami, 2009). In this paper, an innovative simple and practical method through reinforcing column cover plate will be introduced.

2. PROPOSED CONNECTION

To enhance the connection behavior, it is proposed to replace parts of the column cover plate situated in critical areas where the beam flanges (or flange plates) connect to the column cover plate with CJP groove welds, by thicker and larger plates (Deylami and Gholipour 2010). These new reinforced plates will be welded all around their edges to the column members and their adjacent cover plates (Figure 2).

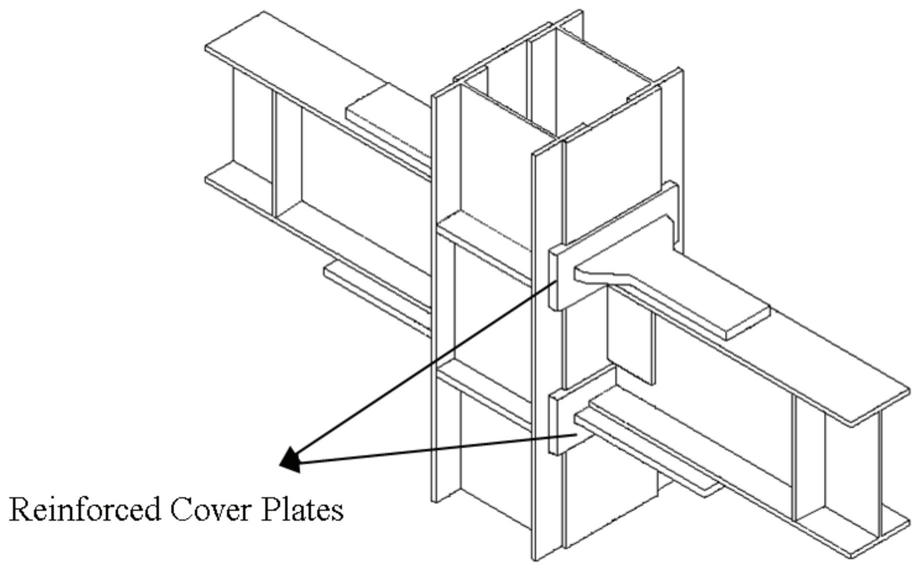


Figure 2: Proposed moment connection of I-beam to double-I built-up column.

The increased thickness of cover plate along with its edges welded all around, result in a more stiffened cover plate which will decrease its out of plane deformation during load-transferring process. Also increasing the width of the column cover plate in front of the flanges of the beam provides the possibility to increase the width of the beam flange plates. This enables us to increase the length of CJP groove weld, which in turn decrease the stress on the weld and the probability of brittle fracture.

3. FINITE ELEMENT MODELING AND ANALYSIS

To investigate the cyclic behavior of the proposed connection, nonlinear finite element analyses were carried out using three different models. The general set-up and configuration of employed sub-assemblage models were selected according to AISC Seismic Provisions (2005) and FEMA-350 (2000). This model is shown in Figure 3.

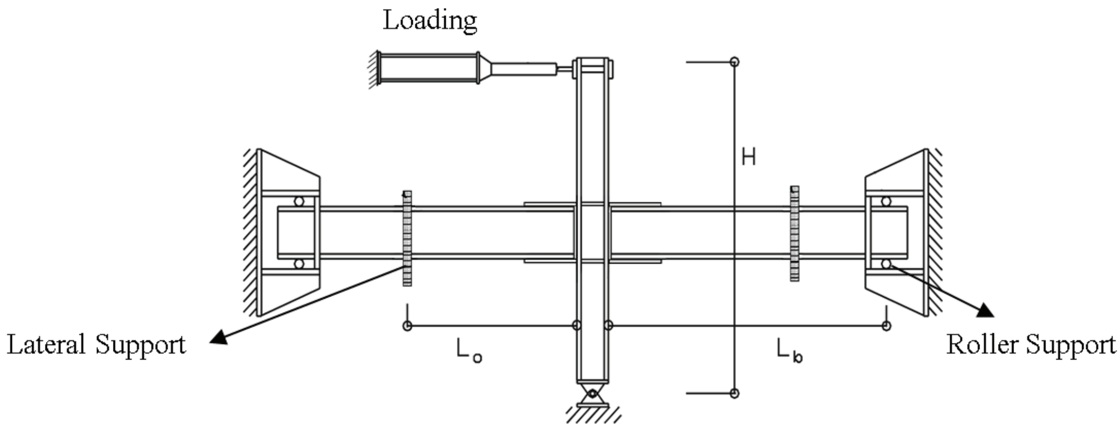


Figure 3: Sub-assemblage model.

Table 1: Models details

Model Name	MP1	MP2	MP3
Beam length (l_b)	240 cm	240 cm	340 cm
Column length (H)	300 cm	300 cm	300 cm
Lateral support distance (l_o)	105 cm	150 cm	200 cm
Beam section	IPE200	IPE270	IPE400
Column section	2IPE180	2IPE240	2IPE300
Column cover plate	PL180*8	PL220*10	PL330*15
Reinforced cover plate	PL220*60*18	PL280*110*20	PL460*110*25
Beam top-flange plate	Figure 4-a	Figure 4-b	Figure 4-c
Beam bottom-flange plate	PL220*150*18	PL300*200*20	PL560*300*30
Shear tab	PL120*80*8	PL150*100*10	PL250*150*15
Doubler plate	PL200*150*10	PL270*210*15	PL400*330*25
Continuity plate	PL160*45*18	PL220*60*15	PL340*85*30

The lateral support distances l_o are chosen according to AISC Specification (2005). Details for all models are presented in Table 1.

ST37 steel with yield strength of 2400 Kg/cm^2 and ultimate strength of 3700 Kg/cm^2 was considered for all elements. To introduce the material properties, a bilinear model with the elastic modulus equal to 2.10E+06 Kg/cm^2 and the tangent modulus equal to 6500 Kg/cm^2 was employed. The considered plasticity model was based on the Von Mises yielding criteria.

For three-dimensional modeling, solid element (SOLID45) available in ANSYS program was employed. Also contact elements (CONTA173 and TARGE170) were used under column cover plates to consider the cover plate deformation. All three models were loaded on their column tips according to the cyclic loading pattern recommended by AISC Seismic Provisions (2005) for moment connections (Figure 5). Nonlinear static analyses were done for all models.

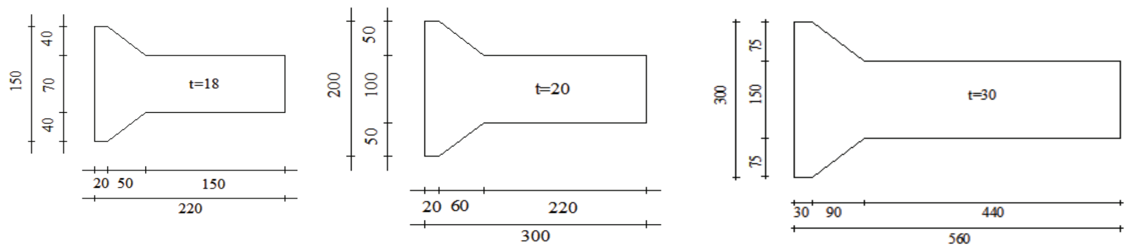


Figure 4: Beam top-flange plate; (a):MP1; (b):MP2; (c) MP3.

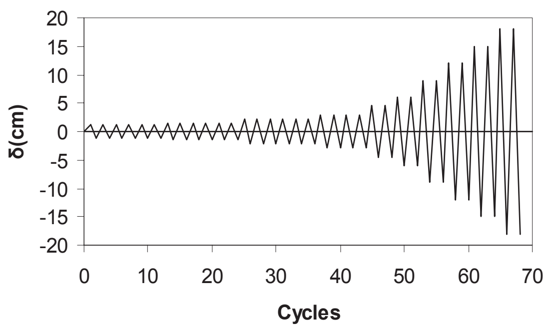


Figure 5: Loading pattern.

4. RESULTS AND DISCUSSION

4.1. Stress and strain contours

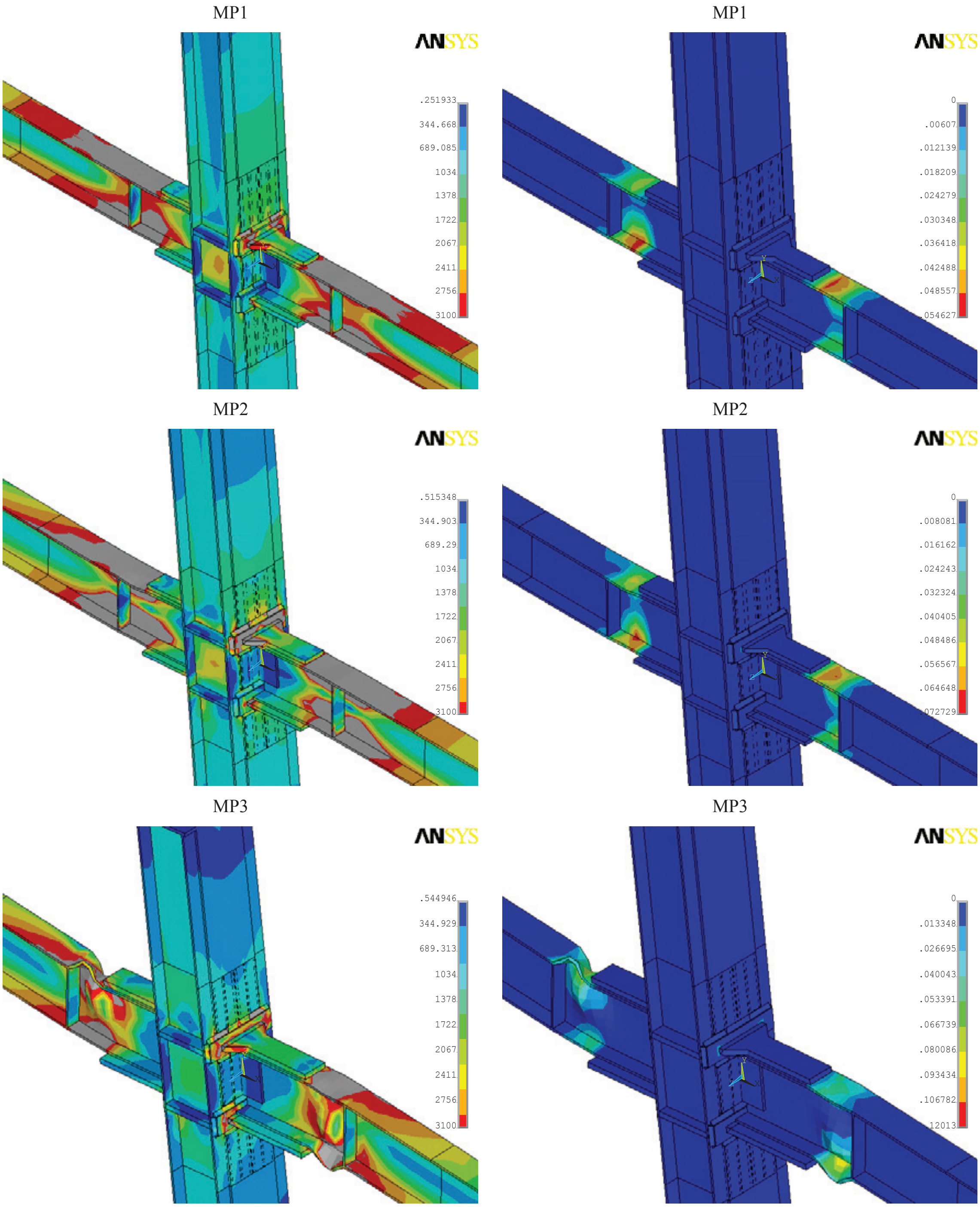
For all models, Von Mises stress and strain distribution contours in the last step of loading are presented in Figure 6. As it can be seen, plastic hinges occur in beams and the panel zone remains in elastic state.

4.2. M-θ curves

M-θ hysteresis curves for all models are presented in Figure 7. As it can be seen, the proposed connection provides good hysteresis behavior with high strength and ductility. All models develop the interstory drift angle of 0.04 radians with flexural resistance moment larger than 0.8Mp. So according to AISC Seismic Provisions (2005), the proposed connection can be used in special moment frames. To have a comparison between different models, M-θ curves for all three models are presented in Figure 8. As it is anticipated, moment capacity increases with the increase in beam height. On the other hand, increasing of beam height increases the probability of buckling and therefore loss of strength which can be seen as a drop in M-θ curve for MP3 model in Figure 8.

4.3. Connection stiffness

In accordance with the AISC Specification (2005), stiffness calculations for all three models are presented in Table 2. As it can be seen for all models, the stiffness ratio (KsL/EI) is greater than 20, which classified these connections in the range of fully restrained connections.



a) Von Mises stress contour b) Von Mises plastic strain contour

Figure 6: Stress and strain distribution contours; (a) Von Mises stress contour; (b) Von Mises plastic strain contour

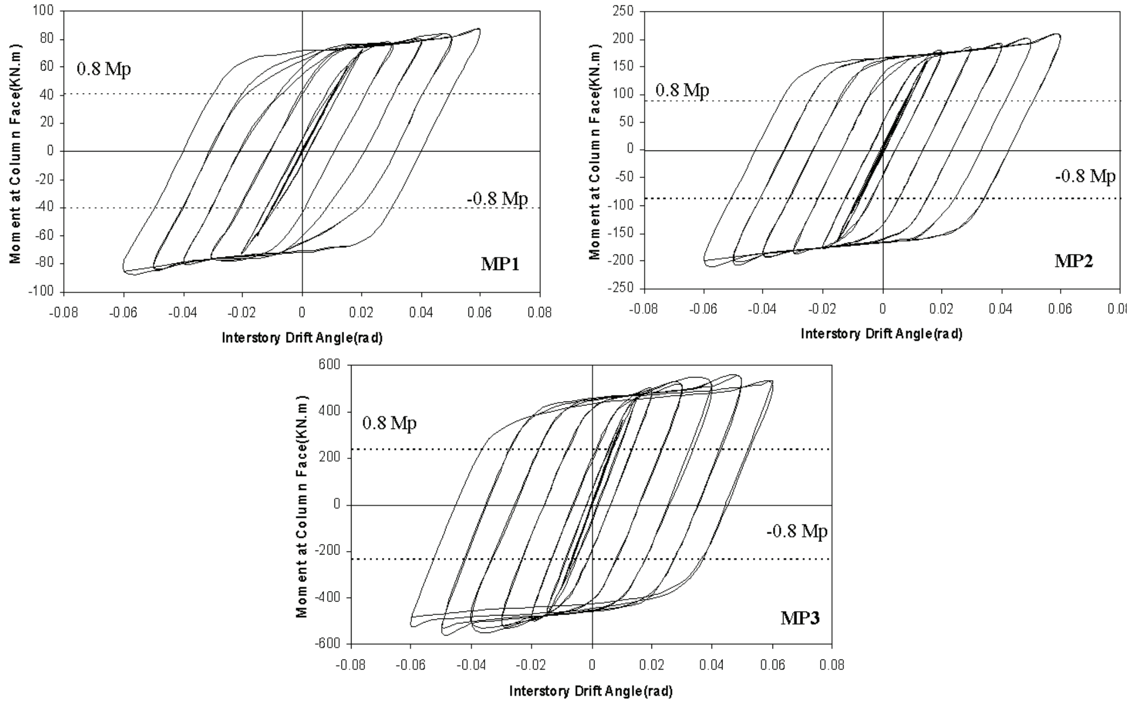


Figure 7: M-θ hysteresis curves.

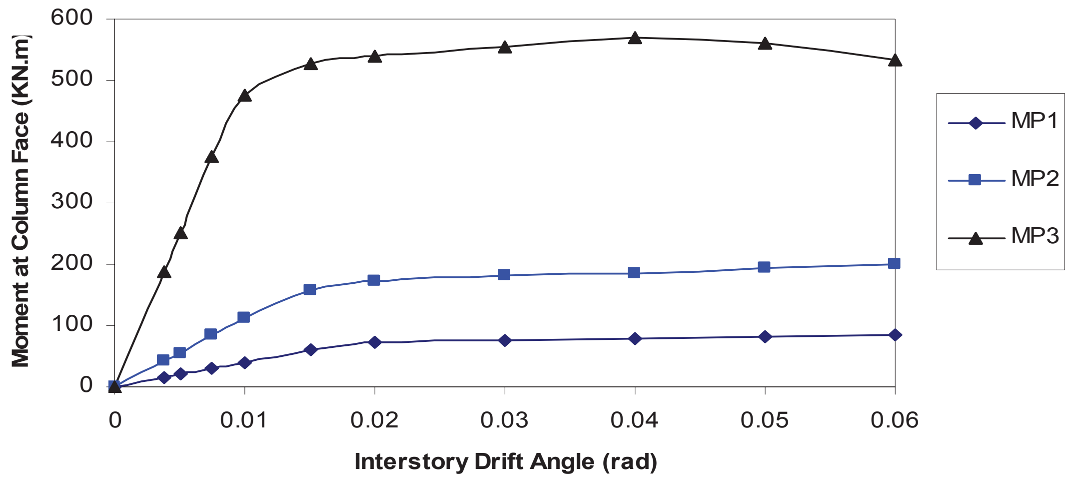


Figure 8: M-θ curves for all models.

5. CONCLUSIONS

In this research, it is proposed to modify the traditional moment connection of I-beam to double-I built-up column by reinforcing column cover plate. To investigate the cyclic behavior of the proposed connection, a series of nonlinear finite element analysis were done. Conclusions are as follow:

- In the modified connections, plastic hinges occur in beams and there is no evidence of plasticity in panel zone region.
- The modified connections provide such a high strength and ductility capacity that can be used in special moment frames.
- While the traditional moment connection acts in a semi-rigid manner, the modified connections show rigid behavior.

Table 2: Stiffness calculations

Model Name	Ms (KN.m)	Φ s (r a d)	k_s (KN.m)	I (m ^ 4)	L (m)	$K_s L/EI$
MP1	46.56	1.34E-03	3.48E+04	1.94E-05	4.80	41.00
MP2	102.96	1.37E-03	7.50E+04	5.79E-05	4.80	29.60
MP3	278.4	1.18E-03	2.36E+05	2.31E-04	6.80	33.06

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