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Study of the effect of skewed beam-to-column connections on loss of strength in endplate moment connections

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ABSTRACT: Skewed beams may be utilized due to the architectural limitations. The use of skewed beam cause to initiation of torsional moment, in addition to flexural moment, at the connection face. In the beams with end plate connections, the torsional moment creates shear stress at the end plates which in combine with the shear stress due to connection shear force can lead to reduction in the connection frictional strength and the end plates slippage. This paper investigates the slippage of the end plates of skewed beam with rigid connection to columns with end-plates. 122 finite element non-linear models are used to study the end plate moment connections with skewed beams with 10, 20, 30 and 45 degree of deviation in the plan. The results showed that for the beams with low degree of deviation, the addition of one or two rows of bolts is a suitable method for reducing the loss of strength for skewed beams. For high deviation angle of 45 degree the friction strength loss is considerable and so large number of bolts may be required to be added to recover the friction strength loss, which may not be possible due to the geometric limitations of the connection and so it is recommended in the beams with 45 deviation angle other types of connections to be used.

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1. Introduction

Analytical studies on the seismic performance of skewed beam to column rigid connection have shown that strength loss in the skewed beam connections occurs earlier than the non-skewed beams [1, 2]. Studies on the performance of the skewed beam to beam, and skewed beam to column connections show that the deviation angle between the skewed beam and the column flange should be limited to 30 degree [3]. Investigations on the behavior of skewed extended shear tab connections show that, the shear tab's twist increases with increased connection orientation due to additional torsional moment. Additionally the connection's vertical displacement slightly decreases as connection orientation increases. The shear tab's torsional strength equation in the American Institute of Steel Construction (AISC) manual 14th edition [4] was modified to consider the additional torsional moment added to the shear tab due to the connection orientation [5, 6].

In the present study, seismic performance of the skewed beam to column connection with end-plates is investigated. Different deviation angles are employed to evaluate the effect of the beam deviation angle on the strength loss of the connection. Some recommendations are presented to improve the behavior of the connections with skewed beam.

2. Methodology

Figure 1 shows the typical finite element model. Different connections with different geometry of beams and columns are considered. Each connection is modeled with deviation angles of 0º, 10º, 20º, 30º, and 45º.

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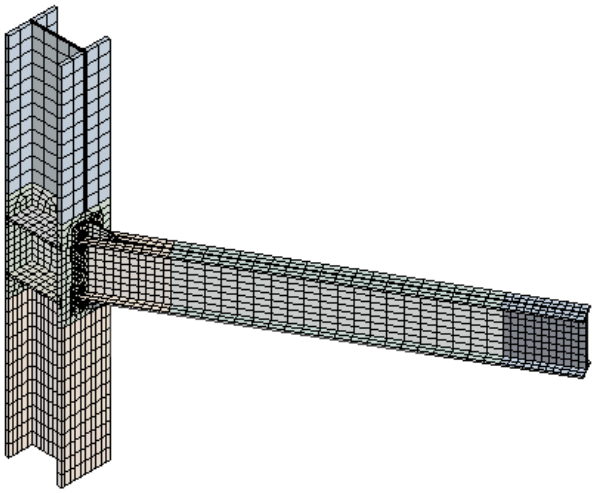

Figure 1. Finite element model of skewed beam to column connection.

Applying a vertical load to the end of a beam with no deviation angle creates a bending moment in the beam-to-column connection. However, in skewed beams, the created moment is comprised of a bending moment and a torsional moment as shown in Figure 2. The torsional moment (M×Sinα in Figure 2) creates a shear stress which will be added to the shear stress due to the shear force. Increasing the deviation angle results in a rise in the shear stress due to larger torsional moment and it might lead to slippage in the connection face.

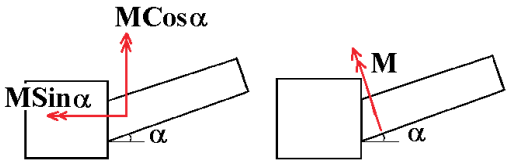

Figure 2. Bending and torsional moment in the skewed beam to column connection.

3. Results and Discussion

In order to study the effect of the torsional moment on the behavior of the connection, frictional strength force between the end plate and the column face in the models are compared with each other. In order to reduce the strength loss of the connections with skewed beam, it is possible to add some bolt rows to the connections. Figure 3 shows the friction force-rotation diagram of one of the models with deviation angle of 45º. In this figure, "8bolt" represents the preliminary designed connection. On the other hand, "10bolt" and "12bolt" represent the connections with one and two additional rows of bolts, respectively. As can be seen adding the number of bolts results in an increase in the frictional strength of the connections.

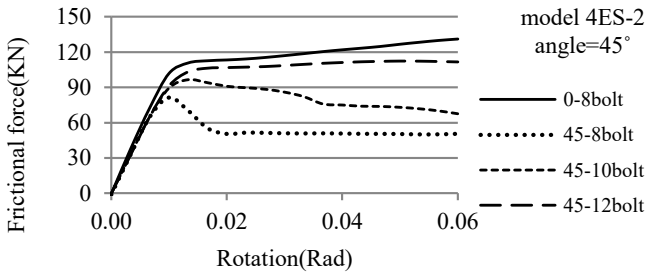

Figure 3. Effect of the number of bolts on the friction force-rotation diagram of 4ES-2 model.

In the preliminary stages of the loading, shear force is transferred to the column through the friction between the end-plate and column flange. After slipping occurs between the end-plate and column flange, the shear force transfers through bearing of the bolts and friction between the plates. The friction and shear force of the non-skewed and skewed beams with deviation angle of 45º are compared with each other in Figures 4 to 6.

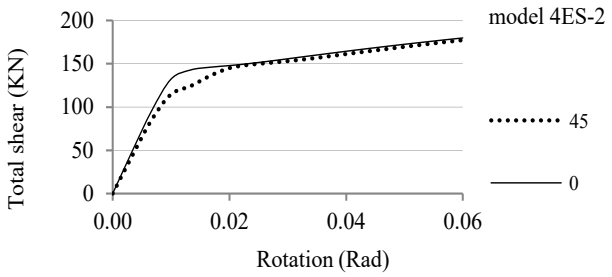

Figure 4. Shear force-rotation diagrams of 4ES-2 model.

According to Figure 4, it can be concluded that deviation angle does not have a considerable impact on the total shear force transfer capacity of the connection. It should be noted that according to Figures 5 and 6, in skewed beam connections, shear force transfers to column through bearing of the bolts, while friction plays the most important role in transferring the force in non-skewed connections.

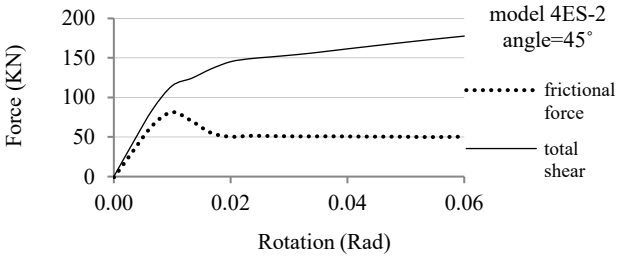

Figure 5. Friction force-rotation vs. shear force-rotation of 4ES-2 model with deviation angle of 45.

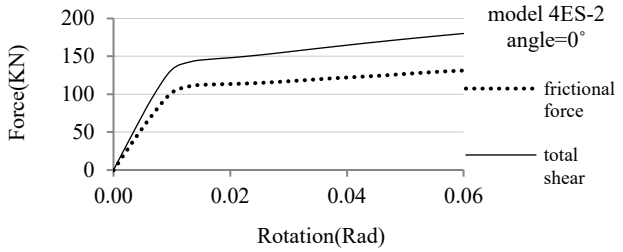

Figure 6. Friction force-rotation vs. shear force-rotation of 4ES-2 model with non-skewed beams.

4. Conclusions

In the skewed beam to column connections, a torsional moment as well as a bending moment will be transferred to the column. Shear stress due to the torsional moment will be added to the shear stress due to shear force and as a result, frictional strength of the connection reduces. In this study, behavior of the skewed beam to column connection was investigated. 122 models were simulated and based on the results, following conclusions can be drawn:

In the skewed beam connection, increasing the number of bolts is a more effective method than increasing the size of bolts. According to the provided results, it can be concluded that adding one row of bolts is sufficient to reduce the frictional strength loss in the connection with deviation angle of 10º, 20º, and 30º.

It is observed that if the deviation angle reaches 45º, increasing the bolt size is not an effective method anymore. It is also observed that excessive increase in the bolt diameter results in connection strength loss which is due to the smaller contact area between the end-plate and column flange.

The results showed that the beam length has little effect on the friction loss of the connections of the skewed beams. With the increase of the beam length, the flexural moment increases, resulting in the increase of the torsional moment. On the other hand long beams have less shear force. Since the slippage of end plates depend on the combined shear stress due to the torsion and the shear force, it is not possible to make sure that the shear stress will be increased or not.

In the skewed beam connection the total shear transfer capacity is mainly based on the bearing of the bolts, while in the non-skewed beams it is mainly based on the friction strength.

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