FE ANALYSIS OF CONNECTIONS WITH ANGLES SUSTAINING HIGH TENSION IN BOLTS

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1. INTRODUCTION

In recent years, semi-rigid connection has probably become more familiar in the area of steel frame analysis and design. With reference to practical application of semi-rigid steel frame construction, AISC-LRFD specification (1994) was adopted a new regrouping of semi-rigid connections as PR (partially restraint) connection. In spite of recognition of PR construction, the new specification did not provide design guidelines for the semi-rigid connections. It occurs from the lack of sound understanding in deferent aspects of the behavior of semi-rigid connections. To overcome this, several experimental and analytical studies had been done so far. Most of the analytical studies for modeling of connection behavior existed with some shortfalls. As for example, Kishi-Chen power model (1990) gained popularity for its easy application in second-order frame analysis with semi-rigid connections. However, the stiffness and pretension of bolts have not been considered for the prediction of ultimate moment capacity and initial stiffness of connection, respectively. In this point of view, top- and seat-angle connection as a category of semi-rigid connections has been studied using finite element (FE) methodology to investigate the following: 1) applicability of FEA method and power model prediction; 2) bolt pretension effect on prying and connection behavior; and 3) influence of connection parameters on prying.

2. CONNECTION MODEL AND ANALYSIS

Geometrical properties of connection models used in FE analysis are listed in Table 1.First two models nominated as ‘A1’ and ‘A2’ in the table are taken from experiments of Azizinamini et al. (1985) and the others are designated by the authors for parametric study on connection behavior. As an example, a half of mesh for connection model A1 is shown in Fig. 1.

Yield stress and ultimate strength for angels, beam, and column are assumed as 365 MPa (53 ksi) and 550 MPa (80 ksi), respectively, for all connection models. These properties are taken from Azizinamini et al.'s test data (1985). Material properties for bolts are assumed as nominal values of A325 bolts based on AISC-LRFD specifications because no coupon test results have been reported and the yield stress and ultimate strength of bolts are taken the respective values of 635 MPa (92 ksi) and 830 Mpa (120 ksi). A bi-linear elasto-plastic stress-strain relation with isotropic hardening rule for plastic deformation of all connection members is assumed taking Young’s modulus $E = 206$ GPa and Poisson’s ratio $\nu = 0.3$, in which strain hardening constant is determined assuming that the ultimate strain for bolts is 10% and for the other connection members is 20%.

Numerical analyses of connection models are performed by using ABAQUS code (1998) developed based on Finite Element Methodology. All connections are modeled using first-order C3D8 solid elements. Bolt pretension level for all connection models except FE5 and FE6 is prescribed as 40 % of ultimate strength of bolt, and for connection models FE5 and FE6, as 20% and 60%, respectively. Connection model A1 is reanalyzed ignoring bolt pretension, which is designating as A1np. Small sliding contact pair definition is applied for the contact surfaces between the vertical leg of angle and column flange, between the horizontal leg of angle and corresponding beam flange, and between the bolt and bolt hole elements.

Table 1 Geometrical properties of FEA model

FEA model	Column section	Beam section	Top and seat angles			Bolt diameter (mm)
			Angle section	Length (mm)	Gage on vertical leg (mm)	
A1	W12×96	W14×38	6×4×$^3/_8$	203	64	22
A2	W12×96	W14×38	6×4×½	203	64	22
FE1	W12×96	W14×38	6×4×¾	203	64	22
FE2	W12×96	W14×38	6×3½×$^3/_8$	203	51	22
FE3	W12×96	W14×38	6×6×$^3/_8$	203	114	22
FE4	W12×96	W14×38	6×4×½	203	64	19
FE5	W12×96	W14×38	6×4×$^3/_8$	203	64	22
FE6	W12×96	W14×38	6×4×$^3/_8$	203	64	22

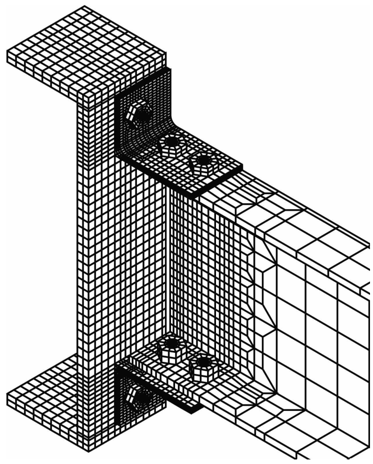

Fig. 1. Mesh of FEA model A1

Key words: semi-rigid connection, moment-rotation behavior, prying action, finite element method, monotonic loading

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3. RESULTS AND DISCUSSION

3.1. Verification of FEA Model

To examine the applicability of FEA model of top- and seat-angle connections, numerical analyses results together with the prediction curve of power model by Kishi-Chen (1990) are compared with the experimental ones and it is shown in Fig. 2. Although the comparison shows that analytical results differ a little from experimental ones in the plastic region, still it can apply for the investigation of prying effect on connection parameters.

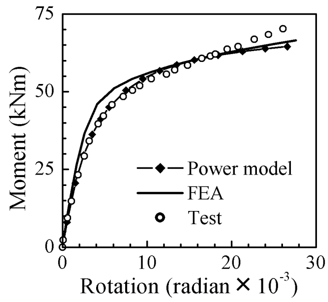

Fig. 2. Performance of FEA

3.2. Stress-Deformation Behavior of connection

Figure 3 shows Mises stress and deformation plot of connection model A1at the ultimate state. The figure reveals that the horizontal maximum displacement is occurred at the heel of top angle, though the vicinity of bolt hole of top angle's vertical leg is severely deformed. In this figure, Mises stress distribution shows that comparatively higher stresses develop near the bolt hole and fillets of top angle. The bending moment surcharged to the beam end is converted to tension and compression forces in the connection and the tension force is transferred to the column flange through the bolts. As a result, a reaction force develops on the top angle's vertical leg between the top edge and the bolt hole centerline. This reaction force lets the bolts increase in tension, is known as prying force. So, the tension bolts are loaded by prying force as well as pretension force and flange force.

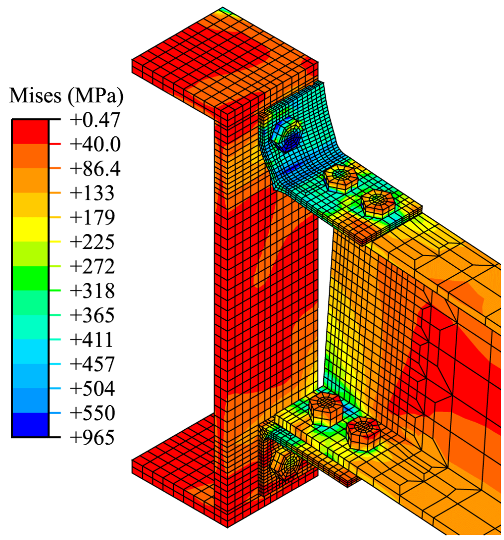

Fig. 3. Stress-deformation plot of Model A1 at the ultimate state

3.3. Bolt Pretension effect on prying and Connection Behavior

Numerical results for models A1np, FE5, A1 and FE6 are compared as shown in Fig. 4, of which introduced pretension forces (T_0) are equal to 0, 20, 40 and 60 percents of ultimate strength of bolt, respectively. All the other properties are the same among four models. It can be observed in Fig. 4(a) that bolt tension force for each model started from different stages rises up to the same level at the ultimate state of connection. The moment-rotation characteristics in Fig. 4(b) show that initial connection stiffness increases gradually corresponding to bolt tightening force raising from 0 to 192.6 kN.

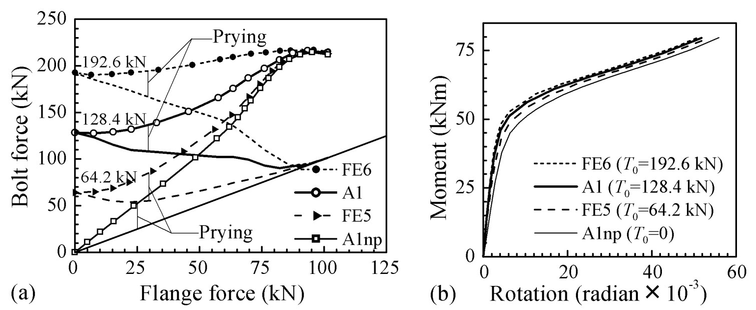

Fig. 4. Pretension effect on: (a) prying, and (b) moment-rotation behavior

3.4. Influence of Angle Thickness on Prying

Numerical results for models A1, A2, and FE1 are compared as shown in Fig. 5, in which angle thicknesses are varied from 9.5 mm (? inch), through 19.1 mm (¾ inch). It is observed from Fig. 5 that bolt tension force in the connection model A1 reaches the ultimate state most rapidly among the three models. It occurs because prying force develops earlier with decreasing angle thickness.

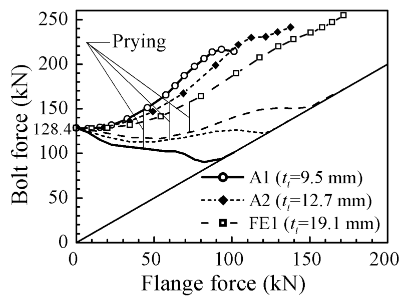

Fig. 5. Influence of angle thickness

7. CONCLUTIONS

After examining the applicability of FE technique and power model, a parametric study was conducted varying connection parameters and pretension force surcharged to the bolts to investigate their affection on prying. This study reveals that:

1) Power model has potential to predict moment-rotation curve of the connection.
2) Bolt pretension does not effect on prying at the ultimate state of connection.
3) Reduction of flange angle thickness develops large prying force.

REFERENCES

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