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ELASTO-PLASTIC FEM ANALYSIS OF TOP- AND SEAT-ANGLE WITH DOUBLE WEB-ANGLE CONNECTIONS

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1. INTRODUCTION

In the LRFD Specification [1], AISC categorizes steel beam-to-column connections into two groups: 1) FR (Fully Rigid)－refers to *Type I* construction; and 2) PR (Partially Rigid)－refers to *Type II* and *Type III* construction. The scenario of semi-rigid construction design guidelines still remain the same with rigid construction because no specific guidelines are prepared in LRFD specification. However, in engineering practice, there are several steel beam-to-column connections, which can be categorized as semi-rigid connection. One of those, popular in practice, is top- and seat-angle with double web-angle connection. This study is focused on finding a suitable predicting technique of moment-rotation behavior of top- and seat-angle with double web-angle connections under monotonic loading. It examines FEM analysis and power model, to investigate the applicability of FEM technique and to check the performance of power model [2].

2. FINITE ELEMENT MODEL SELECTION

Primarily four three-dimensional finite element models are set with the ABAQUS [3] code in order to rationally simulate the stiffness and strength pattern of the connection. The connection is modeled by using C3D8 brick elements. The geometrical properties are taken from Azizinamini et al. [4] test data and the material properties are shown in **Table 1**. The four models can be characterized as follows:

Table 1 Material properties of connection elements used in the analysis

Connection components	Yield stress, ksi	Ultimate strength, ksi	Elongation, %	Modulus of elasticity, ksi	Poisson's ratio	Steel designation
Bolt	100.0	150.0	8	29000	0.3	A325
With 3/4-inch. bolt diameter						
Flange angle, web-angle, beam, Column	40.65	68.43	20	29000	0.3	A36
With 7/8-inch. bolt diameter						
Flange angle, web-angle, beam, Column	39.55	67.95	20	29000	0.3	A36

First Model－The first model is shown in **Fig. 1(a)**. In this model, all bolts are considered to provide support the angles monolithically acting with the beam/column flange/web. Therefore, in designing the mesh, all bolts are considered as a part of the monolithic support and are not represented in the mesh. Contact interaction areas for the flange angles have a width equal to angle length and a length equal to $(g\text{-}w/2)$. Here, g is the gage distance showing the distance from the bolt centerline to the point of angle heel; and w is the width of bolt head. Similar interaction area for web-angles is assumed.

Second Model－Likewise to the first model, all bolts are also assumed to support the angles monolithically acting with beam/column flange/web. The difference between the first and second models is that in the latter, interaction area starts from bolt centerline. That is the contact interaction areas for the flange angles have an width equal to angle length and a length equal to g (**Fig. 1(b)**). Similar interaction area for web-angles is also assumed.

Third Model－The mesh pattern of the third model is shown in **Fig. 1(c)**. The connection is represented by all major connection components: angles, beam, column and bolts. The bolts are represented in details such as: bolt shank, head and nut. The bolts in top- and seat-angles are assumed to behave into two parts: angle side bolt and flange side bolt. The angle side bolt is considered to be a monolithic part of angle while the flange side bolt is assumed to be a part of flange. Similarly, bolts of web-angles also constitute of two parts belonging to angles and beam web/column flange.

Key words: connection stiffness and strength, finite element method, moment-rotation behavior, semi-rigid connection, monotonic loading

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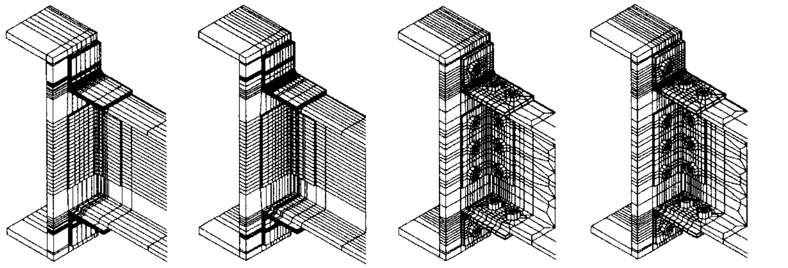
Fourth model — Figure 1(d) shows the mesh pattern of the fourth model. Similar to the third model, this model also represents the connection with bolt details (shank, head and nut). But in this model, the bolts are assumed to interact with the angles and flange/web and completely independent from angle/flange/web.

The comparison of performances of the above mentioned four models in terms of moment-rotation behavior is shown in **Fig. 2**. It is obvious that among the four models, the fourth model performs the best in predicting moment-rotation behavior of the connection and it best represents the real interactions among the connection components. With this background, the fourth model is finally chosen for the present study.



(**a**) First model (**b**) Second model (**c**) Third model (**d**) Fourth model

Fig. 1(a)–(d). Mesh patterns of FE models

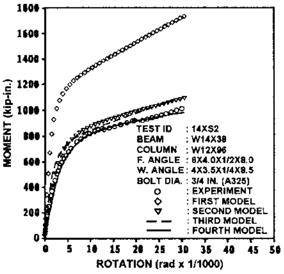


Fig. 2. Comparison among models

3. RESULTS AND COMPARISON

Eighteen bolted connections, whose tests were conducted by Azizinamini et al. [4] are analyzed using fourth model and their results are represented here. The $M\text{–}\theta_r$ curves obtained from FEM analysis together with Kishi-Chen power model [2] and experimental data are shown in **Figs 3(a)–(b)**. The figures show a good match among those three results. With reference to ultimate moment capacity, maximum error of each FEM analysis ranges from -15.96% to +10.86%, and the comparison also shows that power model has the ability to predict moment-rotation relation of top- and seat-angle with double web-angle connection satisfactorily.

4. CONCLUSIONS

A comparison study among the FEM analysis results, power model prediction, and experimental results reveals that,

1. FEM technique can be a viable approach in establishing semi-rigid frame analysis, but this procedure can consume much time for design purpose.

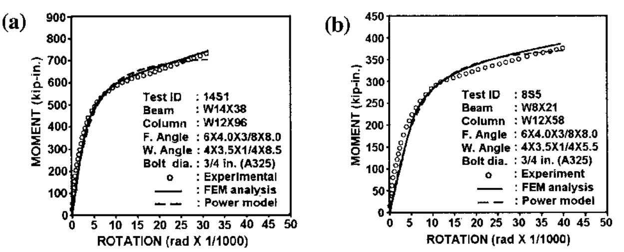


Fig. 3(a)–(b). Performance of FEM analysis and power model

2. FEM technique can be a better alternative from the conventional approaches for cyclic loading study.
3. As far as monotonic loading is concerned, power model can be a good choice for designer estimating moment-rotation relation of semi-rigid connections and for structural analysis of flexibly jointed frames.

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