SEISMIC BEHAVIOUR OF MOMENT CONNECTIONS OF BOXED-COLUMN WITH SIDE PLATES

F.NATEGHI.A[1] and Z.S.TABATABAEI[2]

[1] *Professor , Dept. of Structural Engineering, International Institute of Earthquake Engineering (IIEES), Tehran, Iran*

[2] *Research assistant, Dept. of Structural Engineering, International Institute of Earthquake Engineering (IIEES), Tehran, Iran*

Email nateghi@iiees.ac.ir, z.tabatabaee@gmail.com

ABSTRACT :

Use of side plate in moment connections has enhanced the seismic behavior of connection specially in retrofitting project. The geometry of this connection eliminates recognized brittle behavioral uncertainties that are intrinsic with the use of a T-joint complete-penetration groove weld to connect beam flanges directly to a column flange. The significance of these uncertainties is characterized by unprecedented financial losses that resulted from the Northridge Earthquake.

Results of an analytical investigation of cyclic behaviors of 13 models with side plates between IPE beam and box columns are presented in this paper. The analysis was conducted using the ANSYS 5.4 software. The results indicate that this type of connection has sufficient stiffness, strength and ductility to classify it as rigid, full-strength, ductile connection. Therefore this paper will present the models, finite element procedures and results obtained in this study which all indicate enhanced behavior resulted from using side plates in this type of connections.

KEYWORDS: SIDE PLATE, MOMENT CONNECTION, SYCLIC BEHAVIOUR.

1. INTRODUCTION

Following the January 17, 1994 Northridge earthquake (magnitude 6.7), in the wake of discovering that the "traditional" prescriptive steel moment-resisting frame connection had suffered unexpected widespread premature brittle fracture of welds and base metal, structural engineers were faced with a connection crisis.
Different practical solutions for each type of damages in this earthquake were proposed.
Side Plate (SP) connection system, invented by David L. Houghton, S.E., CEO [3] , is one of the proprietary connection designs as discussed in FEMA350 [2], chapter 3.8.Following the Northridge earthquake. Several innovative engineering firms designed and begin to market alternative moment connection details and president of the Side Plate System, Inc.
In this paper effects of beams and columns sizes and side plate thickness on syclic behaviour of connection are discussed.

2. ATTRIBUTES OF THE CONNECTION SYSTEM

.

2.1. Column/Beam Separation

SidePlate™'s trademark geometry provides physical separation between the face of column and end of beam by means of parallel full-depth side plates (see Figure 1). This key attribute eliminates reliance on brittle and premature behavioral uncertainties that are intrinsic to moment connections that employ the use of a T-joint complete-penetration groove weld to connect the beam's flanges directly to the column flange.

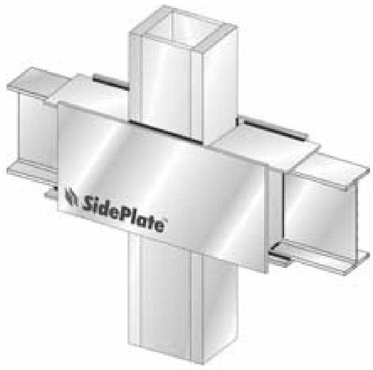


Figure 1. Side plate system

2.2. Full-Depth Side Plates

SidePlate™'s use of full-depth side plates ensures that all significant energy dissipation/connection deformation occurs ductilely outside the column, and connection welds and plates.

2.3. Shop Fillet-Welded Column Tree Construction

For new construction, SidePlate™ uses all shop fillet-welded fabrication, ductile weld configurations, and the column tree/link beam erection sequence for increased quality control and cost efficiency.

2.4. Simplified Load Paths

SidePlate™ combines redundant simplified load paths. Actual load transfer (i.e., load distribution), from beam to side plates and/or brace to side plates, and from side plates to column, is accomplished by the use of plates and fillet welds loaded in a predictable manner.

3. SELECTED MODELS

To scrutinize the behavior of this innovative connection under the cyclic loading and to compare the side plate connection system with the other pre-qualified moment-resisting connections, a series of computational research were carried out. In the first part, we have studied the effect of geometric parameters on the behavior of the side plate moment connections. Thirteen computer models were considered. We have studied the effect of:

tsp = Thickness of side plates.
tsh = Thickness of vertical shear plates.
tcov = Thickness of top and bottom beam flange cover plates.

The selected columns are BOX40*40*2 and BOX30*30*2 shapes. The beams are IPE shapes of 300, 270,240,220, and 200 mm depth. The geometrical characteristics of the models are shown in table 1 and 2.
The finite element computation has been carried out with aid of ANSYS [6], which is a general purpose non-linear finite element program. The selected element was Solid 45. This element has 8 nodes with 3 degrees of translation freedom (in x, y and z direction) per nodes.

Table 1. Geometrical characteristics of general models.

Model Name	Column Profile	Beam Profile	tsp	Lsp	hsp	tsh	tcov	Lcov
SPT1-1	BOX30*30*2	IPE20	1.5	74	25	8	0.8	24
SPT1-2	BOX30*30*2	IPE22	1.8	84	27	8	0.8	29
SPT1-3	BOX30*30*2	IPE24	2	94	29	8	0.8	34
SPT1-4	BOX30*30*2	IPE27	2	84	32	10	1	29
SPT1-5	BOX30*30*2	IPE30	2.2	94	35	10	1	34
SPT1-6	BOX40*40*2	IPE20	1.5	94	25	8	0.5	29
SPT1-7	BOX40*40*2	IPE22	1.8	104	27	8	0.5	34
SPT1-8	BOX40*40*2	IPE24	2	114	29	8	0.6	39
SPT1-9	BOX40*40*2	IPE27	2.2	124	32	10	0.8	44
SPT1-10	BOX40*40*2	IPE30	2.5	134	35	10	0.8	49

*(cm)

Table 2. Geometrical characteristics of models with different side plate thickness.

MODEL NAME	t sp	L sp	H sp	t cov	L cov	b cov	t sh
SPD1-5	2.2	94	35	1	34	30	10
SPD1-5a	1	94	35	1	34	30	10
SPD1-5b	1.5	94	35	1	34	30	10
SPD1-5c	3	94	35	1	34	30	10

*(cm)

To simulate the size of the real structures the length of the connected beam and column were considered 500 cm and 300 cm respectively. The mesh sizes in different parts of the models were selected regarding the demanded precision. Since the gradient of the stress seems to be more sever near the connected zone, a very fine mesh was used in the vicinity of the connected areas (see figure 2.).

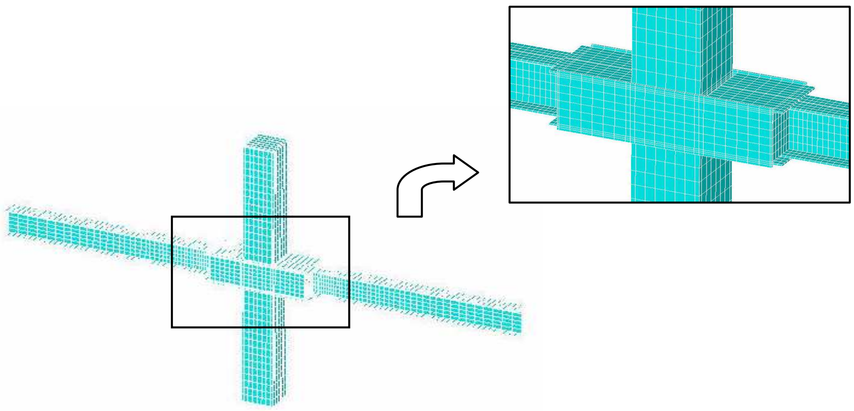


Figure 2. Finite Element Mesh

The boundary conditions for all models were the same. All degrees of freedom at the bottom of the columns were restricted. The nodes on the upper end of columns were restricted in two directions perpendicular to the column, while the horizontal displacements were permitted and the nodes of beam were restricted in two directions perpendicular to the beam too with the horizontal displacements. Each model was loaded on its column tip by imposing cyclic displacement according to the SAC loading protocol (see figure 3.).

Numerical values of θ_j and n_j:

Load Step #	peak deformation θ	number of cycles, n
1	0.00375	6
2	0.005	6
3	0.0075	6
4	0.01	4
5	0.015	2
6	0.02	2
7	0.03	2
Continue with increments in θ of 0.01, and perform two cycles at each step		

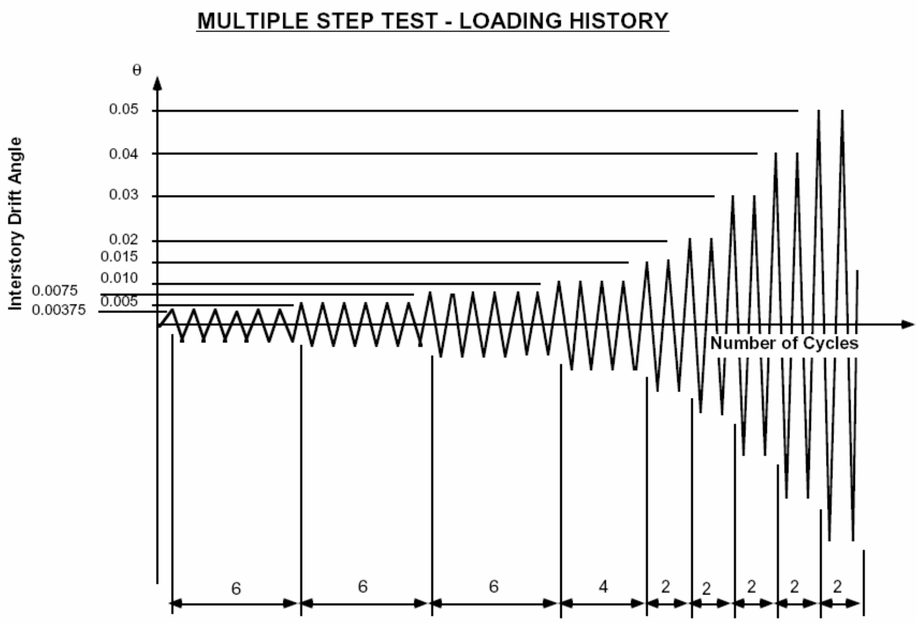


Figure 3 Standard load history, SAC.

A bilinear model was selected to represent the stress-strain curve of material (steel). A line having the slope equal to the elastic modulus of steel (210GPa) presented the elastic behavior of steel. The yield point of steel was considered at 240 MPa. A nearly horizontal line having a slope of 0.135 GPa represented the behavior of steel beyond the yield point (Figure 4). The material considered behaves as kinematic hardening.

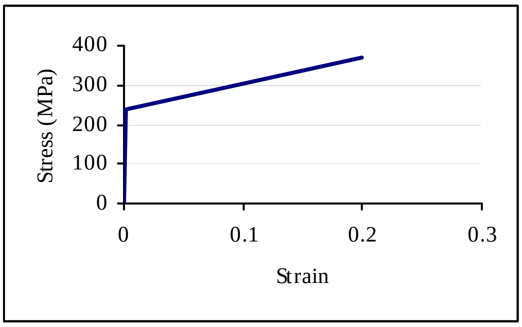


Figure 4. Bilinear model for steel

4. RESULTS

4.1. Effects of beams and columns sizes

The Von-Mises stress distribution for model SPT1-1 is shown in figure 5a. To have a better view of the stress distribution in the interior parts of the connection, in figure 5b we have displaced the side plate. It can be seen that the plastic hinge is shifted from the connected zone toward the beam. This means that, in side plate connections, the brittle fracture of groove weld or formation of plastic hinge in the connecting zone is not the main cause of the damage.

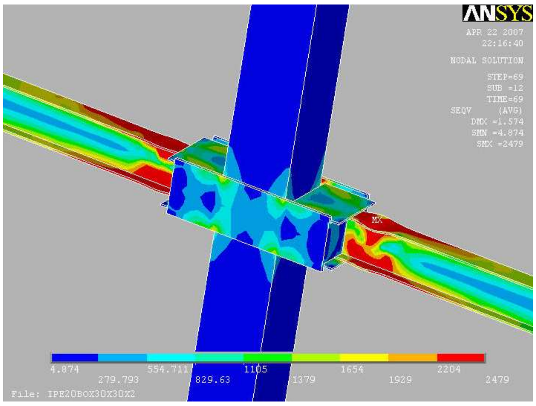


Figure 5a. Stress distribution

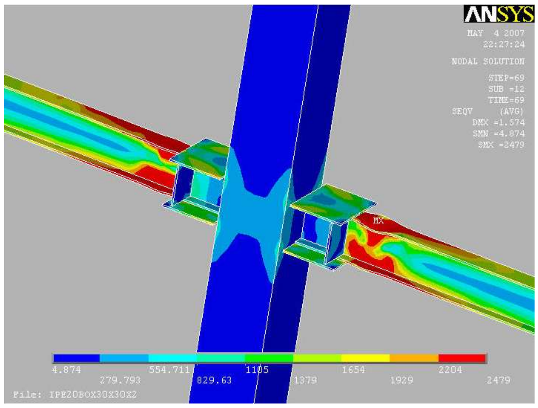


Figure 5b. Stress distribution (interior)

Figure 5. Stress distribution in model SPT1-1

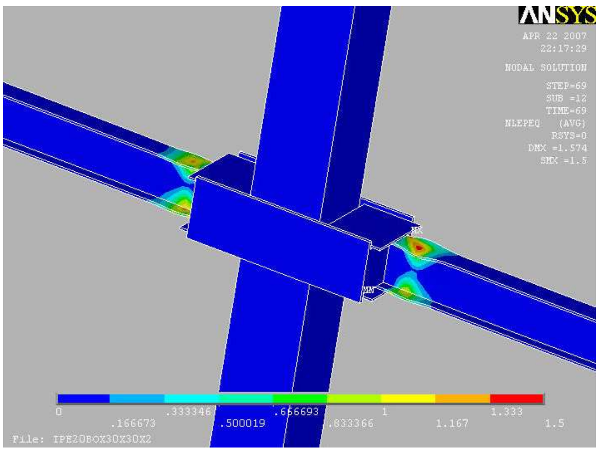


Figure 6. Plastic Strain in model SPT1-1

Another important point shown in figure 5 is that the stress in panel zone remains lower than the elastic limit. This is due to the existence of the two side plates. The reactions are divided into 3 plates (2 side plates and the web of the column).
The plastic strain in different parts of connection is shown in figure 6. We can see that all the plastic deformations take place in the beam, and the connection itself does not withstand the plastic deformation.
It can be noticed that the connections with side plate have remarkable ductility and energy absorption capacity
The moment-rotation (M-θ) diagrams for all models are demonstrated in figure 7. Comparing the moment-rotation curves for different models, it can be seen that the size of columns has negligible effect on the plastic behavior of the models; This should be due to formation of plastic hinge in the beam section, which prevents transferring of deformation to the columns. So we can conclude that all the studied connections can be considered as full strength.

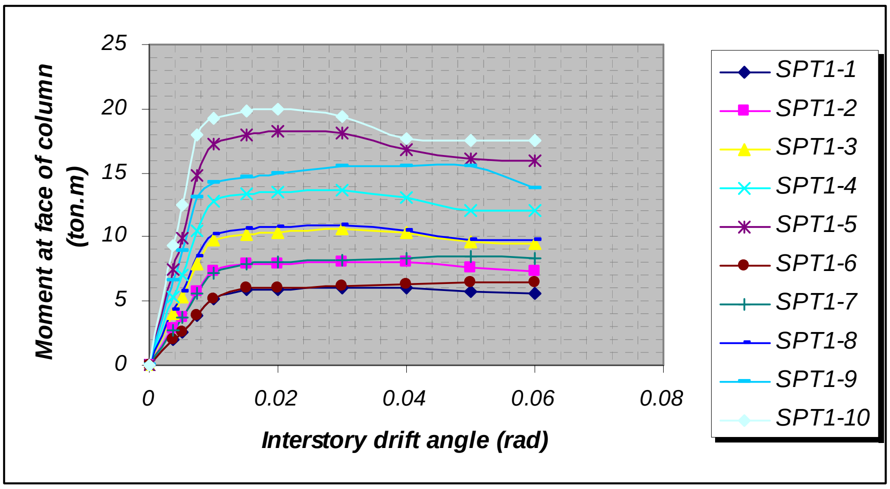
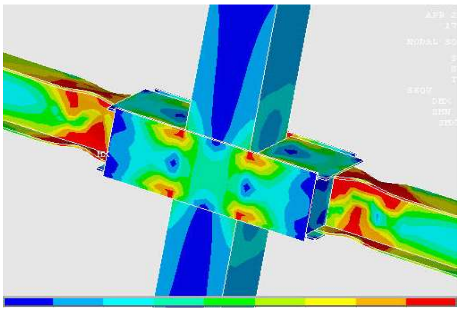


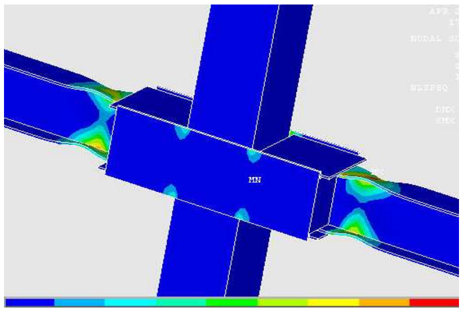
Figure 7. Moment total rotation diagrams

4.2. Effects of side plates thickness

To evaluate the effect of side plate thickness on the behavior of connection, we have studied new models with different side plate thickness. As it is indicated in table 2, we have considered five models, SPT1-5a, SPT1-5, SPT1-5b and SPT1-5c with plate thickness of 10, 15, 22 and30 mm. respectively. The other characteristics of these models were exactly the same.
The distribution of stress and plastic strain for these models are shown in figures 8, 9, 10 and 11. It can be seen that in the case of connection using 10 mm. thick side plates (figure 8) the plastic hinge has been produced in the side plates instead of the beam. The behavior of the models with thicker side plates are nearly similar to each other, except that for the thicker plates the displacements shift toward the beam and the connections behave more stiffly. For the selected models it seems that the optimum thickness for the side plates is 22 mm.
Figure 12 represent the diagrams of moment - rotation (M-θ) for the models SPT1-5, SPT1-5a, SPT1-5b, and SPT1-5c. The only difference between these models is their side plate’s thickness. It is interesting to note that the connection with 10 mm. side plate thickness has less strength and stiffness compared to the other connections with thicker side plates The connection with side plate of 15, 22, and 30 mm.display nearly the same strength and stiffness.

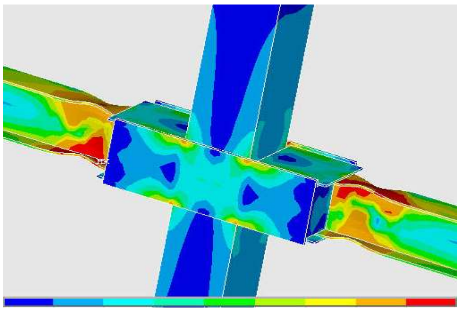


a) stress distribution

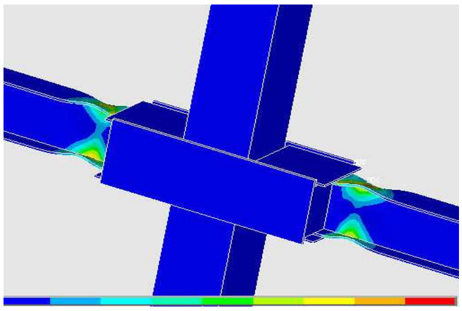


b)plastic deformation

Figure 8. Model SPT1-5a (Side plate Thickness=1)

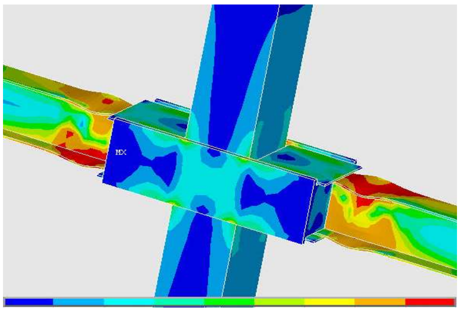


a) Stress distribution

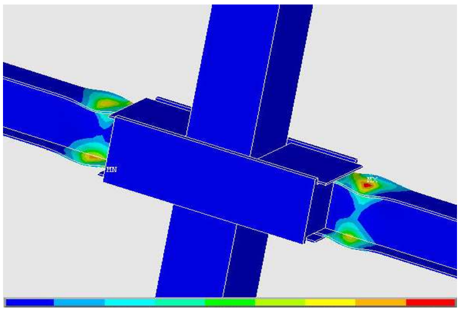


b) plastic deformation

Figure 9. Model SPT1-5b (Side plate Thickness=1.5)

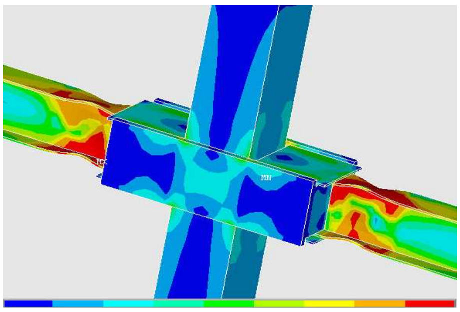


a) Stress distribution

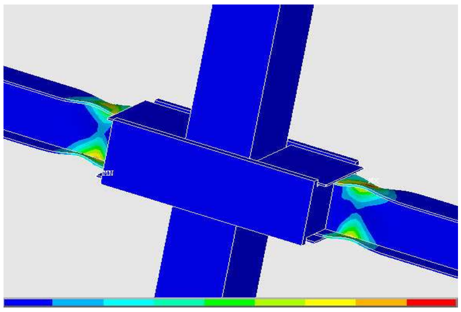


b) plastic deformation

Figure 10. Model SPT1-5 (Side plate Thickness=2.2)



a) Stress distribution



b) plastic deformation

Figure 11. Model SPT1-5c (Side plate Thickness=3)

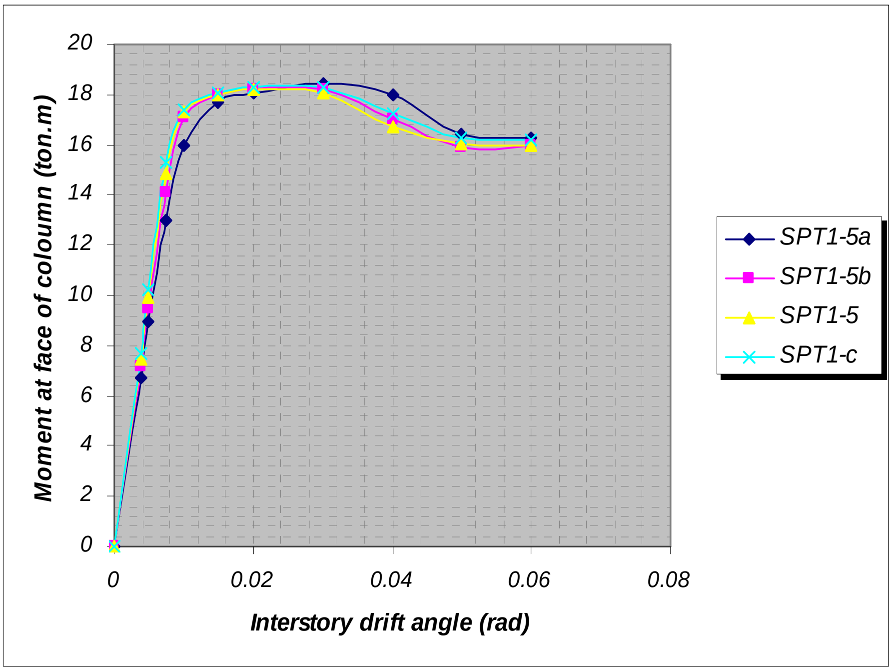


Figure 12. Moment Rotation diagram

5. CONCLUTION

The important results obtained from this non-linear finite element analysis are summarized below:

- Plastic deformations take place in the beam instead of connection.
- Side plate Connections has remarkable ductility and energy absorption capacity.
- Size of columns has negligible effect on the plastic behavior of connection.
- Side plate thickness has negligible effect on the behavior of the connection.

REFERENCE

Engelhard, M.D., Sabol, T.A., Aboutaha, R.S., Frank, K.H., (1995)"Overview of the AISC Northridge Moment Connection Test Program," National Steel World Conference, Texas

Federal Emergency Management Agency, FEMA-350: Recommended Seismic Design Criteria for New Welded Steel Moment Frame Buildings, Sacramento, California, 2000.

Houghton, D.L., (1998) "The Side plate Moment Connection: A Design Breakthrough Eliminating Recognized Vulnerabilities in Steel Moment Frame Connections."Proceedings of the 2nd World Conference on Steel Construction, San Sebastian, Spain.

Davis, J. (2001). "Steel Moment-frame Buildings. Part 2.Structural Engineer. June 2001.

ICBO Evaluation Report No.5366, Side plate Moment Connection Systems, ICBO Evaluation Service Inc., A Subsidiary Corporation of International Conference of Building Officials, 1999.

ANSYS, (1997), Basic Analysis Procedures Guide, Theory and Element Reference Manuals Release 5.4, ANSYS Inc., Canonsburg PA..