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Evaluation of Dynamic Parameters of Steel Knee Bracing System under Seismic Loads

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Abstract:

One of the methods used in the building retrofitting against lateral loads (convergent or divergent) is the use of bracing system. The common picture of convergent bracing causes many common problems in providing the space for building openings. In this study, the seismic behaviour factor (R) for knee-bracing system in steel structures is evaluated. The R factor components including ductility reduction factor and over strength factor are established from inelastic pushover analyses of brace-frame systems of different heights and configurations. to consider the effect of influencing parameters on seismic behavior factor various analysis are performed and the effect of the height of the frame, share of bracing system from the applied load and the type of bracing system are investigated. It is conducted that the length and height of frame s have considerable effect on the R values and their influence does not warrant generalization at this stage. However, the brace area has a profound effect on the R factor, as it directly affects the ductility capacity of the dual system. Finally, based on the findings presented in the article, tentative R values are proposed for steel-knee bracing systems.
Keywords: knee bracing system, ductility, behavior factor, push over analysis

1. Introduction

Providing the strength and ductility of structures are the main objectives of seismic design. The new design philosophy, more particularly, the ductility is more important (AISC 2005). In addition to the structural instances, the designer should consider non-structural constraints and other objectives (Popov 1994). Many researchers have carried out experiments and numerical analyses of BRBs for incorporation into a seismic force resisting system. Yoshino and Karino (1971) performed tests on a brace element comprised of a flat steel plate (a core plate) and reinforcing concrete panels (as a restrainer) with debonding material. The debonding material was used to avoid attachment between the core plate and the restrainer. Watanabe et al. (1988) found that the elastic buckling strength of the restrainer should be larger than the yield force of the core plate for preventing overall flexural buckling of the BRB. Studies on practical applications of BRB to buildings were conducted by Qiang (2005), and design procedures incorporating BRBs into building structures were suggested by Clark et al. (1999) and Choi and Kim (2009). Modeling of hysteretic curves by component tests of BRBs was carried out by Black et al. (2004). From the tests and analysis results, it was concluded that a BRB can be used as a practical and reliable alternative to conventional lateral load resisting systems. A new type of BRB, a double-Tee double-tube BRB (DT-BRB), was suggested by Tsai et al (2002).

Pseudo-dynamic experiments and numerical analyses of a large scale frame with BRBs were conducted by ahnestock et al. (2004), and it was found that the connection at the ends of the BRB should have sufficient stiffness and strength for maintaining stable behavior under maximum compression and tension force. Experimental and analytical studies of a knee brace system were performed by many researchers. Aristizabal-Ochoa (1986) developed a Knee Braced Frame (KBF) as a new alternative structural system for earthquake-resistant steel buildings. Sam et al. (1995) carried out pseusdo-dynamic testing of single and double story KBF models, and showed that the knee brace systems were enough to reduce the damage due to the earthquake loadings effectively and economically.

Such bracings are similar to diametric bracings or V and knee bracing (Balendra, Sam, and Liaw 1990; Maheri, Kousari, and Razazan 2003; Mofid and Khosravi 2000; Mofid and Lotfollahi 2006), with this difference that each member has shifted to a broken line and the place of fracture site is attached to the frame corners by another member (Figure 1). Off-center bracing is privileged to X-bracing due to the provision of more architectural space, but its hardness is less and more buckling of the page (Balendra, Sam, and Liaw 1991; DiSarno and Elnashai 2002). Since most bracing systems in Middle East are used as frames with joint connections, the main part of the building to absorb earthquake energy and to supply sustainability will be bracings. However, since the major reason in energy absorption and earthquake force in structure is ductility, the calculation of ductility and the behavior

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ratio, which reflects the characteristics of the system ductility, is of importance (Chopra and Goel 2002; Iervolino and Cornell 2005).
The main purpose of this paper is to determine the best way to run an intermediate node, and to calculate the coefficient of behavior R (Perotti and Scarlassara 1991) for a knee bracing system under seismic loading. Therefore, using finite element model and software ANSYS (Moaveni 1999), Three one-opening frames with one, two and three story are modeled which all openings have knee bracing.
Each story has 3 meters height and the length of opening is 4.3 meter. The models are a bracing opening of a hypothetical plane with a loading cross section of 20 square meters per floor level. The amount of effective weight in per unit area of floor is assumed 1 ton divided by square meter. Method-based modeling which has been mentioned in Section 4, have been made. Then, the amount of behavior coefficient is determined under the increased static load.

2- knee-bracing system

Knee bracing frames are a modified form of cross bracing in which the brace is cut short and connected to the main point of knee element spaning between the adjacent beam and column. The key component is the knee element, which controls both the initial elastic stiffness of the frame, and the onset of yield and subsequent energy dissipation.
The situation of the connection of brace members to each other (intermediate nodes) determines the space for frame opening (figure 1), if the intermediate node moves towards the frame corner, frame stiffness against lateral loads decrease. The interesting thing about this type of Off-center bracing is that according to the figure 1, due to the effect of lateral load on the right side, three members of left bracing along the right column in tension and three bracing members with the left column are under pressure (Estekanchi, Soltani, and Vafai 2004; Mosalman, Mosalman, and Yazdi 2011).

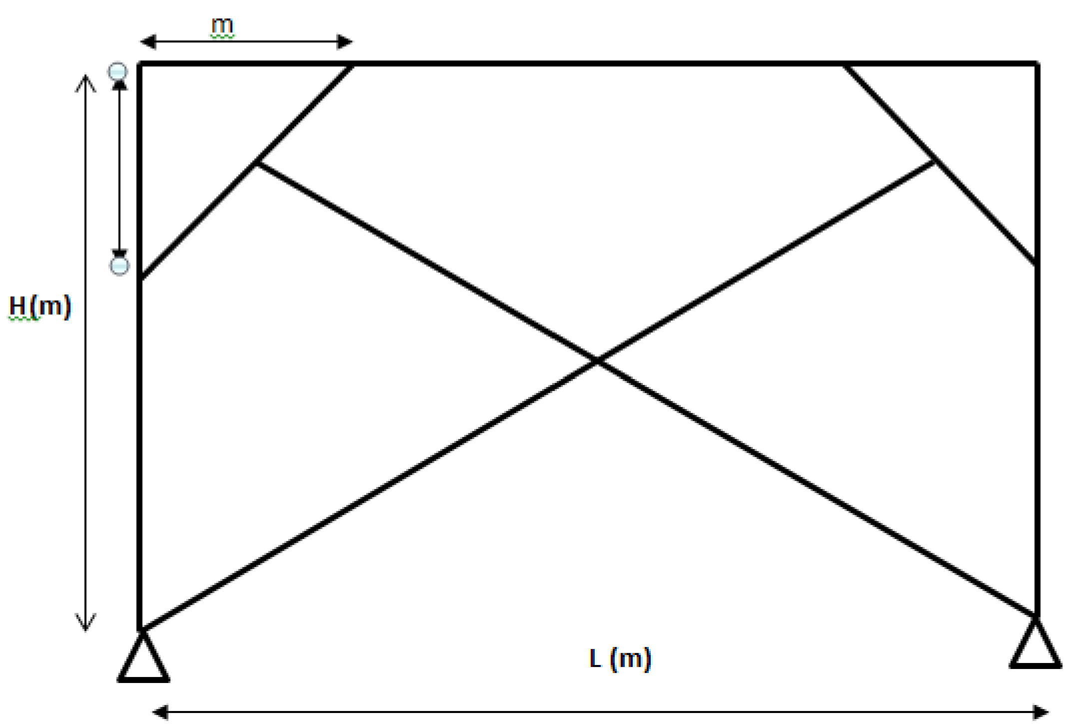


Figure 1:Characterstics of Knee bracing system

3- Modeling and assumptions

Modeling with the finite element method was conducted to evaluate and observe the stresses in different parts of the frame was comfortable and focus on other issues such as the tension focus, local buckling and…have been considered in the model.

Accordingly, the paper is used the software ANSYS for modeling. The elements SHELL 181, SHELL 43, MASS 21 have been used for the modeling. The element SHELL 43 has been used as the modeling for the beam-forming plates, columns, bracings, connection plates and pustules furrow. The element SHELL 43 which is a four node element has been used to model the side welds. The element MASS 21 has been used for the mass of the structure. The assumptions used in this modeling are as follows:

1- Considering the change of nodes in large deformations
2- All yielding materials follow the yielding standard of Van Misses,
3- The effects of axial force is the buckling of the elements

Figure 2 presented the prototype model of a one-story frame with knee bracing under a seismic loading condition..

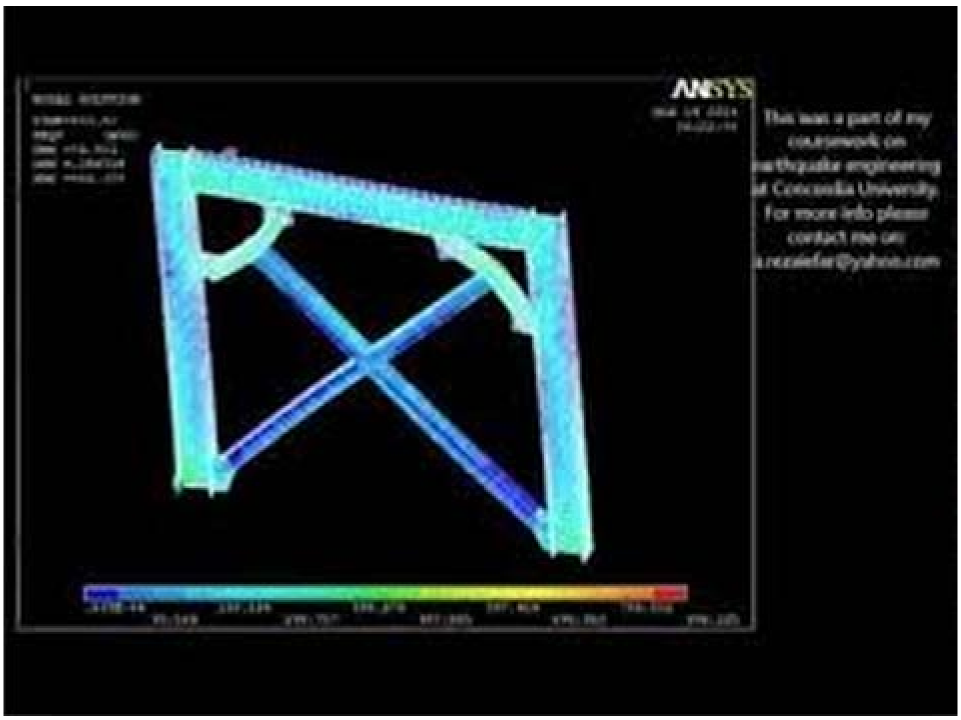


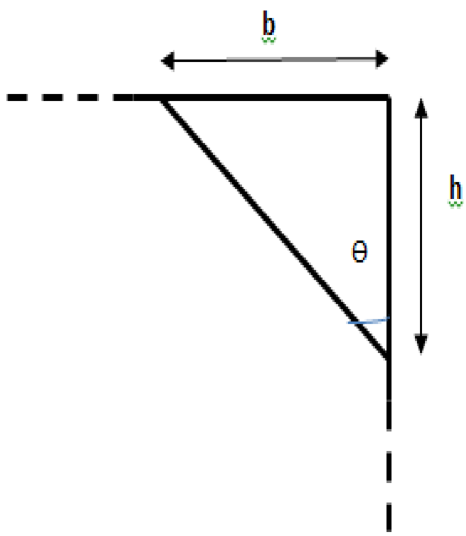
Figure 2 the prototype mode of knee bracing system

3 –Parametric Study

In this section effect of various parameters on dynamic responses on steel frames to take into account the effectiveness of these parameters on behavior factors.

3.1: effect of angle of diagonal member

To investigate the effects of moment of angle of diagonal member of knee bracing, the angle are changed from 13 to 53 (Figure 3.a). Then, they have been analyzed under the increasing load. As it is shown, angle of diagonal member effects on the non-linear behavior of frames with knee bracing. The results are presented in table 1 and is drawn in figure 4 as a function of stiffness of bracing. Survey of the results show that using a single profile causes the buckling of the page of the intermediate nodes under the increasing load . Thus, in implementing this bracing system, single profiles should not be used.



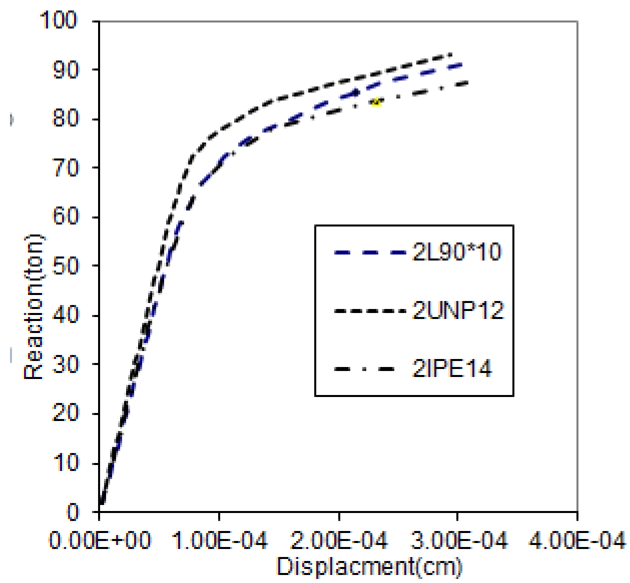


Figure 3.a angle of diagonal member

Figure 3.b the effect of moment of inertia on off-center bracing

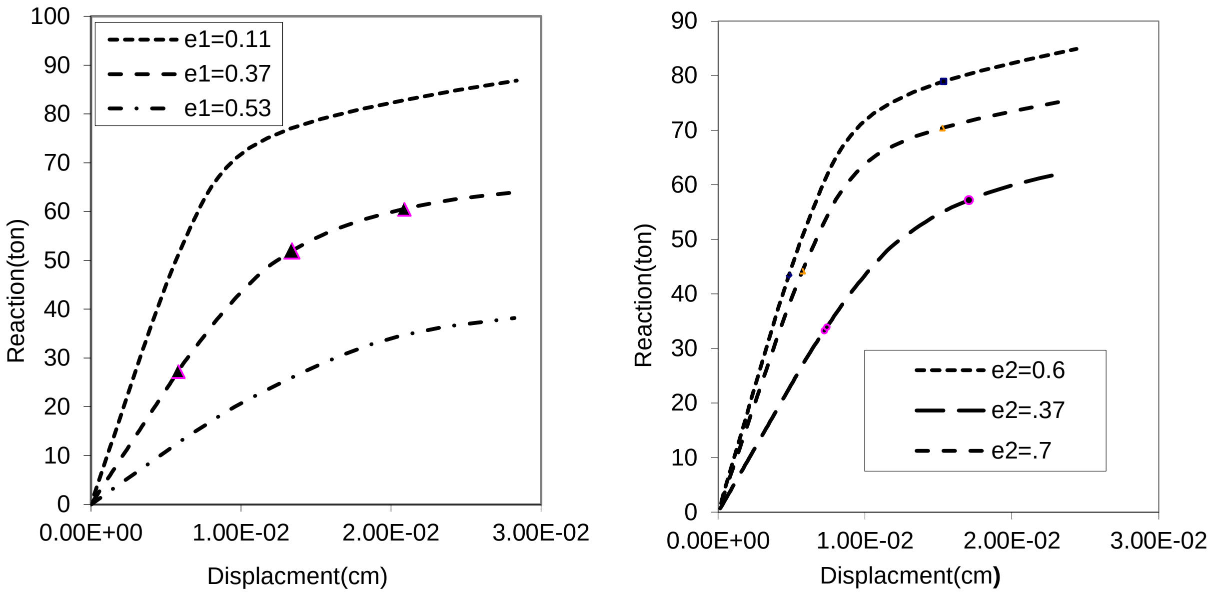
Table1: the effect of angle of diagonal member on dynamic responses

رديف	H (cm)	b (cm)	$\frac{b}{h}$	Θ(deg.)	K (Ton/cm)	$\frac{K}{EI_c / H^3}$
1	131.0	30	0.247	13.8	13.33	102.2
2	122.1	45	0.386	21.4	14.28	109.9
3	117.2	60	0.547	28,8	15.62	119.03
4	103	75	0.75	36.90	17.24	132.4
5	90.50	90.4	1.00	45.6	19.23	147.3
6	83.00	104	1.40	53.23	20.83	159.4

4- Evaluation of the effects of out of center of intermediate nodes on frame behavior

To investigate the effects of out of center of intermediate nodes on frame behavior of knee bracing, two parameters e1 and e2 are introduced.

Figure 5 shows the effect of each of these parameters on the nonlinear behavior of the frame. As can be seen, with increasing departure from the axis e1 and fixed amount of e2= 0.61,because the intermediate nodes moves on the main diameter towards the corners of the frame, the connection place of the beam and column the hardness of elastic stiffness decreased but the hardness of the plastics remained almost constant.



a) The effect of e1 b) the effect of e2

Figure 4 the effect of out of center of intermediate node on the seismic behavior

Also, with the increase of e1, the ultimate strength, ductility decreases. However, with the augment of e2, per the fixed amount of e1= 0.45, the hardness, ductility and ultimate strength increases. In the case that e2= 0.6, the hardness and the ductility reaches their maximum. This is when a connector member of intermediate node is connected to the junction of the middle beam-column in the center of the main diameter member. With increasing e2, the hardness, ductility and ultimate strength decreases.

5- An investigation of the effect of bracing cross section on the non-linear behavior of the

Figure 5 shows the effects of bracing cross section on the non-linear behavior of bracing under increasing static loading. With respect to the corresponding picture, elastic stiffness increased with the augment of bracing cross section, but the plastic hardness remains nearly constant. In addition, final resistance and ductility increases with the augment of braces cross section.

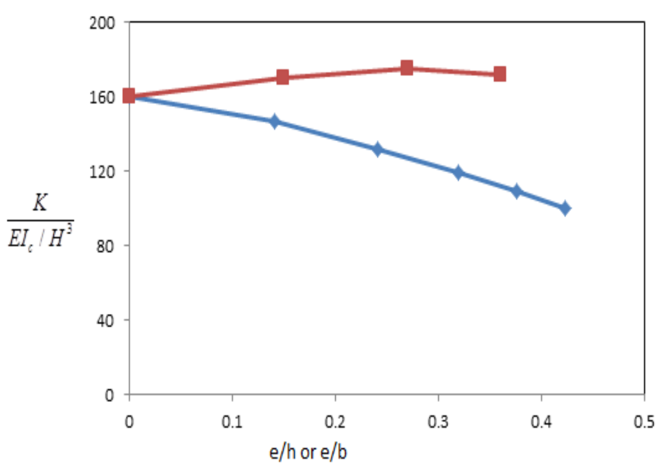


Figure 5 the effect of bracing cross section

6- The calculation of coefficient behavior and ductility coefficient

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Design regulations of the earthquake do not necessitate the structure elasticity in the occurrence of a severe earthquake, but it is authorized to enter the structure into the plastic stage and amortizes the resultant energy of earthquakes in itself. Therefore, in determining the earthquake forces, the linear analysis and permitted stress design should be done to divide the earthquake force per a special coefficient named behavior coefficient. This ratio represents the quake performance and capability of energy absorption. The calculation method of the behavior coefficient and the ductility ability directly affecting the behavior coefficient are presented for two different loading conditions.

6-1-The calculation of the behavior coefficient under the increasing static load

To calculate the behavior coefficient under the increasing static load, the frame was analyzed by Push-over method and the cut curve relevant to the analysis. Point of the curve, where the chart moves from linear to non-linear loss, shows the displacement and force at the moment of the show (Δ_s, V_s).

To calculate the elastic force, the linear part of base shear curve continues the displacement in the same direction linearly to reach the displacement at the final moment (Maheri and Akbari 2003; Reyes-Salazar and Haldar 1999). The base cut pertinent to the ends of the linear section is the maximum base shear in the elastic mode (V_e) .

Behavior coefficient is obtained using the following relations:

A- Behavior coefficient based on the corresponding level with the final load:

$$R = \frac{V_e}{V_s} \qquad (1)$$

B- Coefficient of the corresponding level of allowable stress (Y=1.44):

$$R_W = \frac{V_e}{V_s} * Y \qquad (2)$$

6-2-The calculation of ductility coefficient under the increasing static load

Ductility ratio is the ratio of maximum lateral transform to the yielding lateral transform. Ductility coefficient under the increasing load is calculated based on the initial yielding or the first plastic joint. The ductility ratio is equal to:

In the above relations, the increase coefficient of displacement is obtained from the bilateral relation. Rs is the additional coefficient of the resistance which is obtained from the mutual relation. Au and Vu are the displacement and the final base shear of structure in elastic mode.

In table 1, the results of calculations of behavior coefficient and the ductility for models 1 to 3 story (figures 1 and 6) under the increasing static loading is shown.

7- Summary and Conclusions

Off-center braces have many applications due to providing the space for openings for building retrofitting but it is likely to confront many damages during the severe earthquakes due to the lack of attention to technical standards and the pertinent criteria in the design of these braces. In this bracing system, three elements connected to the intermediate node are stretched on one side and is presses on the other side.

Being pressure of three elements connected to the intermediate node causes the connection point to be exited from the plate in the severe earthquakes. Intermediate nodes to avoid leaving the connectors on this point must be rigid. The position of the intermediate node has a dramatic effect on the behavior of the off-center braces frames. As the intermediate node moves towards the corner of the frame, the connection point of bar with column, the hardness, ductility and the behavior coefficient of the frame decreases.

Also, the use of the single sections for the braces causing buckling of these members under lateral load is relatively low. Determining the behavior coefficient is the critical issues for seismic design of the off-center bracing system. Due to lack of sufficient studies about the non-linear behavior of these bracings, and because these bracings considered as convergent braces, the behavior coefficient of convergent braces, 7 or 8 can be used to design these bracings which is not logical. This paper analyzes the models under two increasing static and seismic loadings to calculate the real behavior coefficients and off-center bracings The studies done have gained the approximate value of the behavior coefficient for designing the extent and Rw= 5 for designing the permissible stress method.

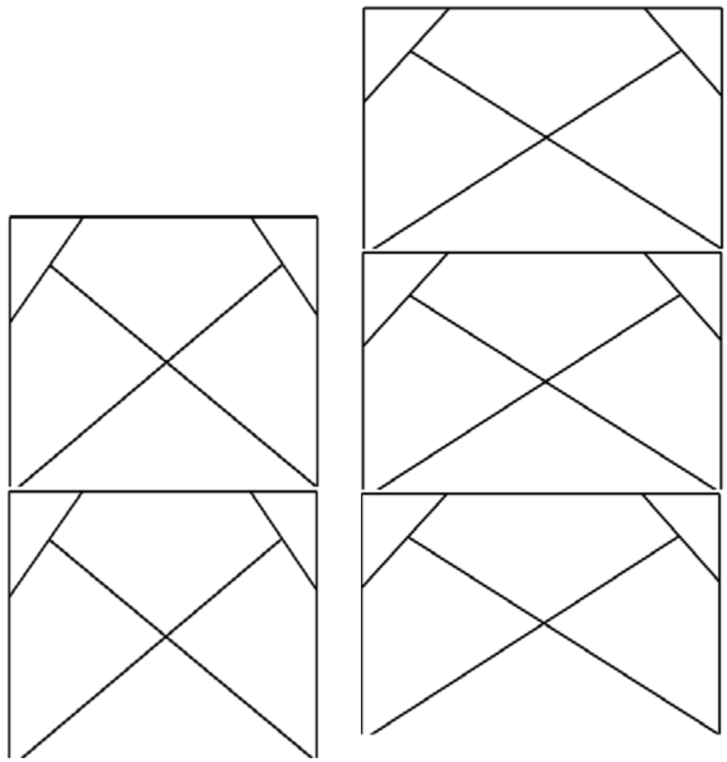

Figure 6 selected steel knee bracing frame with two and three stories

story	R	R_w	R_s	C_d	μ
1	6.7	9.65	1.56	5.2	4.23
2	7.3	9.32	1.89	6.2	5.00
3	7.95	7.20	1.56	6.85	4.95

Table 1 the seismic parameters of selected frame with off-center bracing

8- References

AISC, A. 2005. AISC 341-05 Seismic Provisions for Structural Steel Buildings, American Institute of Steel Construction. *Inc: Chicago, IL*.

Balendra, T., M.T. Sam, and C.Y. Liaw. 1990. Diagonal brace with ductile knee anchor for aseismic steel frame. *Earthquake Engineering & Structural Dynamics* 19 (6): 847-858.

Balendra, T., MT Sam, and CY Liaw. 1991. Design of earthquake-resistant steel frames with knee bracing. *Journal of Constructional Steel Research* 18 (3): 193-208.

Chopra, A.K., and R.K. Goel. 2002. A modal pushover analysis procedure for estimating seismic demands for buildings. *Earthquake Engineering & Structural Dynamics* 31 (3): 561-582.

DiSarno, L., and A.S. Elnashai. 2002. Seismic retrofitting of steel and composite building structures.

Estekanchi, H., A. Soltani, and A. Vafai. 2004. "SEISMIC BEHAVIOR OF STEEL FRAMES WITH OFF-CENTER BRACING SYSTEM." In: Venue West Conference Services Ltd, Suite 645- The Landing, 375 Water Street, Vancouver, B. C, V 6 B 5 C 6, Canada.

Iervolino, I., and C.A. Cornell. 2005. Record selection for nonlinear seismic analysis of structures. *Earthquake Spectra* 21: 685.

Maheri, M.R., and R. Akbari. 2003. Seismic behaviour factor,< i> R</i>, for steel X-braced and knee-braced RC buildings. *Engineering Structures* 25 (12): 1505-1513.

Maheri, MR, R. Kousari, and M. Razazan. 2003. Pushover tests on steel X-braced and knee-braced RC frames. *Engineering Structures* 25 (13): 1697-1705.

Mofid, M., and P. Khosravi. 2000. Non-linear analysis of disposable knee bracing. *Computers & Structures* 75 (1): 65-72.

Mofid, M., and M. Lotfollahi. 2006. On the characteristics of new ductile knee bracing systems. *Journal of Constructional Steel Research* 62 (3): 271-281.

Moghaddam, H.A., and H. Estekanchi. 1995. On the characteristics of an off-centre bracing system. *Journal of Constructional Steel Research* 35 (3): 361-376.

Mosalman, H., and N.R. Sulong. 2010. Parametric investigation on an off-centre braced frame system's stiffness.

Mosalman, M., A. Mosalman, and H.M. Yazdi. 2011. On the connection behavior of gate bracing system. *Scientific Research and Essays* 6 (2): 241-246.

Popov, E.P. 1994. Development of US seismic codes. *Journal of Constructional Steel Research* 29 (1-3): 191-207.

Reyes-Salazar, A., and A. Haldar. 1999. Nonlinear seismic response of steel structures with semi-rigid and composite connections. *Journal of Constructional Steel Research* 51 (1): 37-59.