"Seismic Behavior of Off-center Truss Bracing"

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Introduction

Iran is a country with a high seismic risk in the world. While adobe and masonry buildings are used mostly in rural areas, R/C structures and steel structures are used widely in large cities. Iranian code for seismic resistant design of buildings, published by BHRC (1), was in effect on Feb. 1988. Although this code does not cover rural areas at the moment, the code is to be followed by engineers in urban areas. Frame with bracing system is used commonly to resist lateral seismic force in steel structures. Various types of bracing systems are used by engineers. Among them there is a system called "Y-shape" or "Curtain-shape" bracing system which is used recently by designers (Fig. 1). This system has an advantage of big opening at the middle part (Fig. 1-a, 1-b), compare with conventional diagonal bracing system (Fig. 1-c), which makes it quite attractive for owners. This bracing system can be found also in Eurocode 8 (2). A behavior factor of 4 and 2.5 is proposed for a frame structure with diagonal curtain shape bracing (Fig. 1-a) and v-shape curtain bracing (Fig. 1-b) respectively. This paper compares the behavior of Curtain-shape bracing system with conventional diagonal bracing system. A method to calculate effective length factor *k* is also presented. This paper is a part of ongoing theoretical and experimental research project in collaboration with BHRC and University of Tehran.

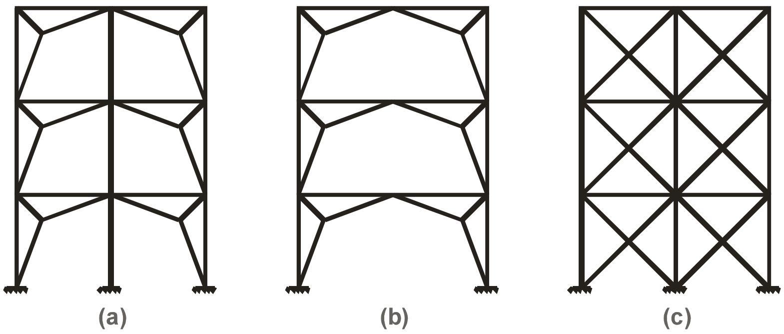

Fig. 1 Frames with Curtain-shape (Y-shape) versus diagonal bracing

Analysis of Frame with Bracing Members in Tension

A closed form solution is developed to calculate lateral displacement of a single-story one-bay braced frame. The closed form solution is used to perform a parametric study for a series of single-story one-bay frames (Fig.2) varying position of intersection point of bracing members. Lateral displacement ratio of curtain type bracing systems to diagonal type bracing system subjected to a lateral load is calculated, graphed, and compared. The lateral displacement ratio can be derived from following Equation (3):

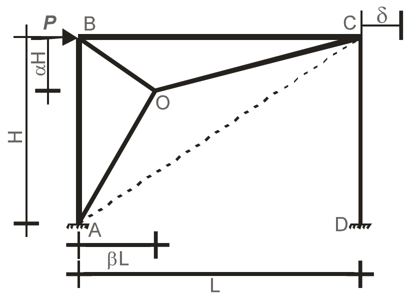

Fig. 2 Single-story one-bay fame

$$\frac{\delta_{curtain}}{\delta_{diagonal}} = \frac{\delta_c}{\delta_d} = \frac{\beta(1-\beta)+m\alpha(1-\alpha)}{\alpha\beta(1+m)} \quad ; \quad m = \left(\frac{H}{L}\right)^2$$

In which; β and α are span length and story height coefficients respectively.

To cover all internal points located above frame diameter, the coefficients can vary as $0 < \alpha < 1$ and $0 < \beta < 1-\alpha$. Totally 54 frames with different bay lengths are analyzed. Among them, 24 frames are for $\alpha = 0.2$, 18 frames for $\alpha = 0.4$, and 12 frames for $\alpha = 0.6$. Figure 3 shows the analysis results. It can be seen that the lateral displacement of a frame decreases, as long as the location of intersection point *O* moves toward the frame diameter. Minimum value of the displacement ratios is equal to unity when the intersection

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point *O* touches the diameter *AC*. In this case, the force of diagonal member *OB* becomes zero. Increasing the bay length leads to a less value of displacement for a fixed position of intersection point. It is worth noting that all three bracing members are subjected to an axial force with a same sign depends on direction of applied lateral load.

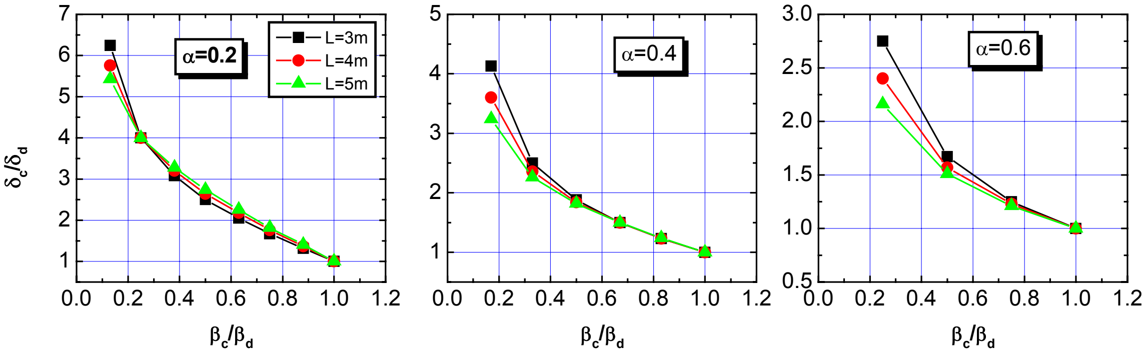

Fig. 3 Lateral displacement ratios of curtain type to diagonal bracing system

Analysis of Frame with Bracing Members in Compression

Bracing members may buckle in-plane or out-of-plane. An effective length factor *k* of unity can be assumed for in-plane buckle mode. A closed form solution is developed to calculate *k* factor for out-of-plane buckle mode. Out-of-plane stiffness of each bracing member *i* at the intersection point *O* can be derived from elasticity equation of a beam (Fig. 4) as follows (3):

$$K_i = \frac{EI_i}{L_i^3}\,\frac{(\mu L)_i^2\left[1-(\mu L)_i\tan(\mu L)_i/\alpha_i\right]}{\left[\tan(\mu L)_i/(\mu L)_i+(\mu L)_i\tan(\mu L)_i/\alpha_i-1\right]};\quad \mu_i=\sqrt{P_i/EI_i}\quad ;\alpha_i=\left(K_\theta L/EI\right)_i$$

In which P_i is axial force of a member and $(K_\theta)_i$ is flexural stiffness of connecting plate at a joint *A*, *B*, or *C*. Bracing system buckles when $\sum K_i = 0$. At this time, critical axial force of each bracing member $(P_{cr})_i$ can be easily derived using equilibrium equation. Consequently, effective length factor *k* becomes:

$$k_i = \left(\frac{P_{cr}}{P_e}\right)_i^{1/2}\quad ;\quad P_e=\frac{\pi^2 EI}{L^2}$$

Conclusion

Intersection point of bracing system should be close to diameter to increase lateral stiffness. Effective length factor *k* of bracing members can be derived using a closed form solution. The *k* factor is depended on geometrical characteristics of frame and stiffness ratio of bracing members to connecting plate.

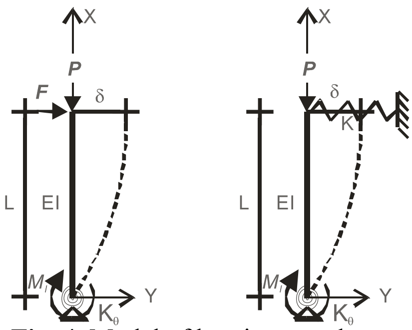

Fig. 4 Model of bracing members

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2. Eurocode 8, "Design of Structures for Earthquake Resistance," Part 3, Dec. 2001.
3. Jouharzadeh, A.M., and Badpar, A., "A study on frames with Y-shape Bracing," MS Thesis, University of Tehran, June 1997.

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