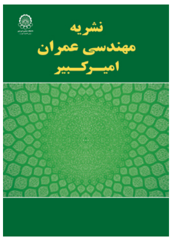

Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 49(1) (2017) 3-5
DOI: 10.22060/ceej.2016.682

The Relative Stiffness of Steel Eccentric Braced Frame with Dual Vertical Links

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ABSTRACT: The most important characteristics of building frames can be abbreviated in stiffness, strength and ductility. Moment frames have ductile behavior and low stiffness; Therefore, the main reason in using the lateral bracing systems is their considerable stiffness. Eccentric bracing systems are considered as ductile frames, while satisfying the required stiffness. The lateral stiffness of conventional eccentric configurations have been calculated previously. In this research, the lateral relative stiffness of eccentrically braced frame with dual vertical links (EBF-DVL) is calculated analytically. EBF-DVL has two parallel vertical links which are welded to the floor beam at the top and to one horizontal link at the bottom. In order to provide the required equations for obtaining the stiffness, the slope-deflection equations are used by considering the effects of shear deformations. The results show that EBF-DVL has a high relative stiffness and by adjusting the lengths of vertical and horizontal links, it is possible to achieve the stiffness even more than the stiffness of eccentric bracing with horizontal link between two diagonal braces. Although an increase in either the moment of inertia or shear area of the vertical link leads to an increase in the lateral stiffness of the system, the effective interval for increasing the moment of inertia of the vertical links is to be limited to approximately half of the column moment of inertia and the corresponding value for increasing the shear area is approximately 60% of the shear area of the column.

Review History:

Received: 16 September 2013
Revised: 10 May 2015
Accepted: 25 January 2016
Available Online: 6 November 2016

Keywords:

Eccentric Bracing
Vertical Link
EBF-DVL
Analytical Relative Stiffness
Shear Deformation

1- Introduction

In recent years, eccentric braced frames with two vertical links have been introduced [1-3]. The authors of this article have been introduced a new configuration for the eccentric bracing systems which can be considered as the combination of inverted-Y and split-K EBFs. It has two vertical links which are connected to a horizontal link at the bottom, while they are attached underneath the floor beam at the top. The resulted braced frame is called EBF-DVL (Eccentrically Braced Frame with Dual Vertical Links) hereafter, and is illustrated in Fig. 1.

In the current research, the relative stiffness of a 1-bay 1-story EBF-DVL will be calculated in elastic range. In order to provide the required relations, the equations of slope-deflection method are used. Since the links' lengths are short in eccentric bracings, so the shear deformations are also considerable. Therefore, the shear included equations of slope-deflection is used. The relative stiffness of the EBF-DVL is obtained as a function of some non-dimensionalized parameters and the relative stiffness variation is investigated by changing some of these parameters.

2- The relative stiffness of the EBF-DVL

Fig. 2 shows EBF-DVL with the required degrees of freedom. By applying the slope deflection equations, the absolute stiffness of the moment frame part, K_{mf}, is obtained as the following:

$$K_{mf} = \frac{2EI_c}{H^2}(6\theta_B + \frac{12}{H}) \tag{1}$$

In which the parameters of I_b and I_c are respectively the moment of inertia for beam and columns and A_b is the cross sectional area of the beam.

The absolute stiffness of the braced frame, K_{bf}, will be:

$$K_{bf} = 2[\frac{2EI_c}{H^2}(3\theta_B + \frac{6}{H}) + \frac{EA_{br}}{L_{br}}(\Delta_1 \cos\theta - \delta \sin\theta)\cos\theta] \tag{2}$$

By dividing the Eq. (2) to the Eq. (1), the relative stiffness of the EBF-DVL, K_{Rel}, is obtained as a function of the following non-dimensionalized parameters:

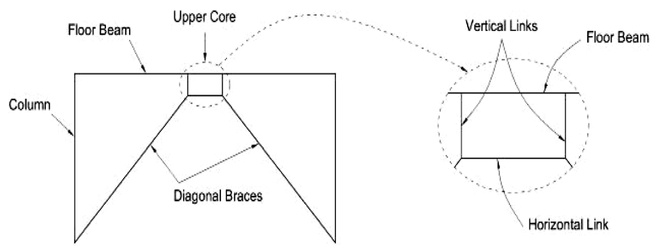

Fig. 1. Schematic layout of an EBF-DVL

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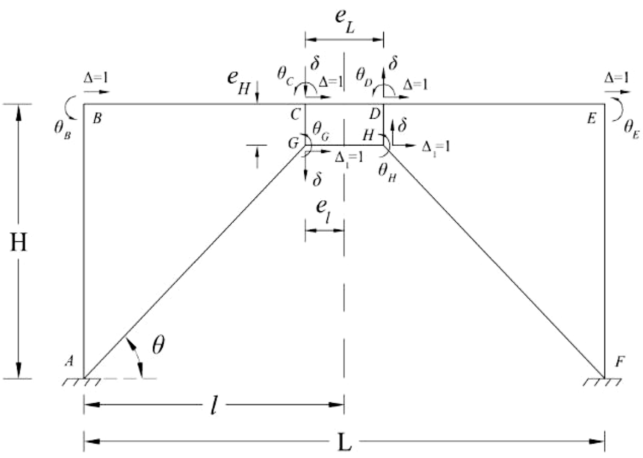

Fig. 2: Moment frame and its degrees of freedom under unit lateral displacement

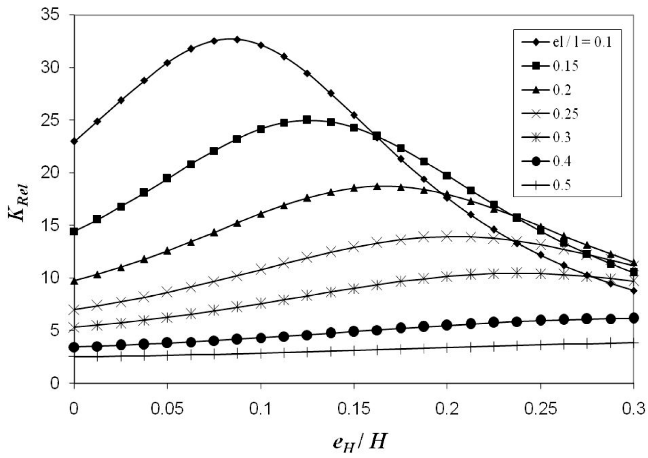

Fig. 3. The variation of stiffness relative to the e_H/H and e_l/l parameters

$$K_{\mathrm{Rel}} = f\left(\frac{H}{l}, \frac{e_l}{l}, \frac{e_H}{H}, \frac{I_b}{I_c}, \frac{I_{hl}}{I_c}, \frac{I_{vl}}{I_c}, \frac{A'_{hl}}{A'_b}, \frac{A'_{vl}}{A'_b}, \frac{I_b}{A_{br} l^2}, \frac{EI_b}{GA'_b l^2}\right) \quad (3)$$

In the above equation, the parameters A'_b, A'_{hl} and A'_{vl} are respectively the shear areas of the beam, horizontal link and vertical links. The parameters I_{vl}, I_{hl}, A_{vl} and A_{hl} are respectively the moment inertia and cross section area of the vertical and horizontal links. In continuation, the variation of the relative stiffness is investigated by changing the non-dimensionalized parameters in Eq. (3).

3- The effect of some parameters on the relative stiffness of the braced frame

3- 1- Eccentricity geometric parameters

Fig. 3 shows the variation of K_{Rel} relative to the geometric parameters of e_H/H and e_l/l. This figure is depicted for the ratio of H/l=1.0, while the other parameters of Eq. (3) are held constant. As predicted, Fig. 3 shows that the relative stiffness decreases by increasing the e_l/l parameter. However, for each constant value of e_l/l, the relative stiffness increases at first by enhancing the parameter e_H/H, and then decreases

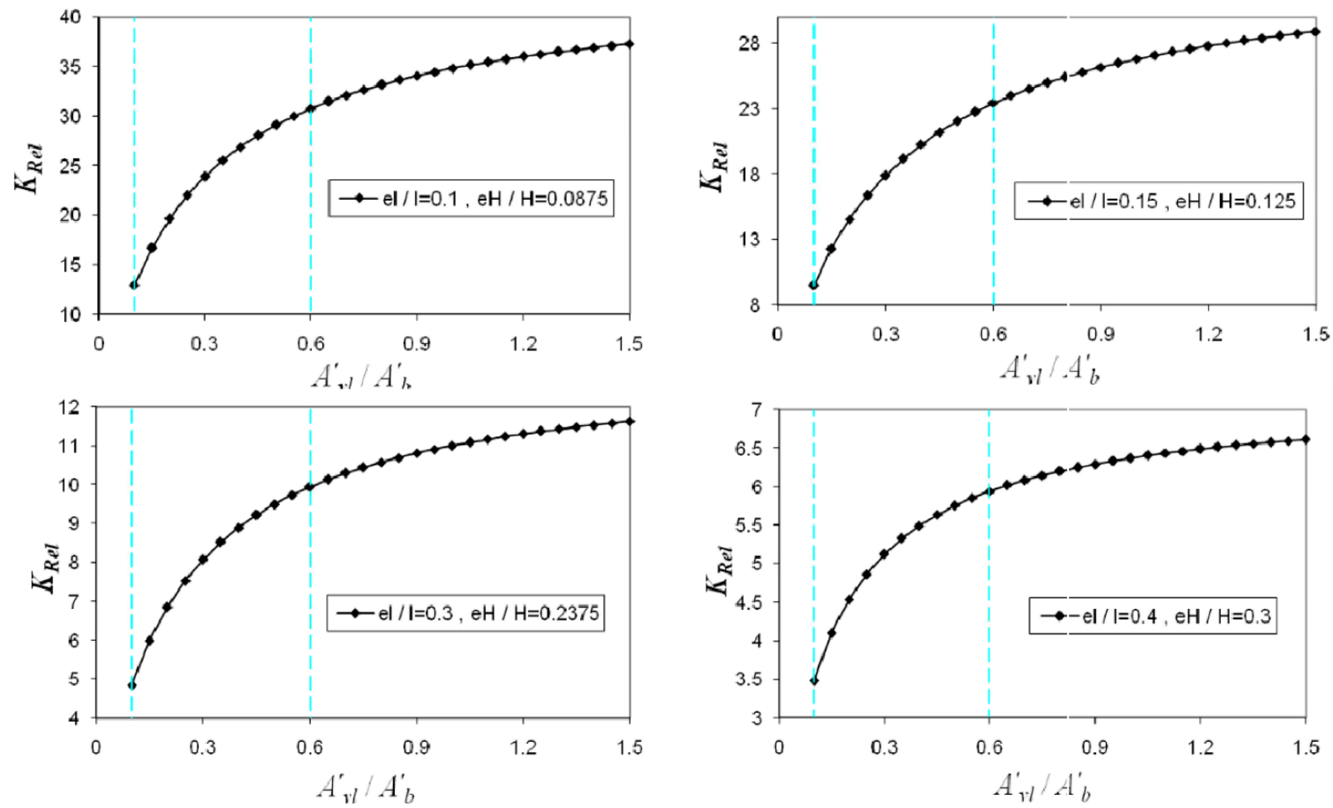

Fig. 4. The variation of stiffness relative to the A'_{vl}/A'_b parameter (H/l=1)

at higher values of e_H/H.
It is clear that the lateral stiffness of the horizontal link EBF (with link beam located between diagonal braces) is slightly lower than the values obtained at the points of $e_H/H=0$. Hence, by choosing an optimum value for e_H/H parameter, the relative stiffness of an EBF-DVL could be even larger than the stiffness of EBF with a horizontal link located between diagonal braces.

3- 2- The moment of inertia of the vertical links

At the lower values of the moment of inertia of the vertical links, the increasing of the I_{vl}/I_c parameter has more effect on the enhancement of the relative stiffness of the frame. The effective and economical span for increasing the I_{vl}/I_c parameter is 0.5. On the other hand, at the small values of eccentricities, increasing the moment of inertia of the vertical links has no considerable effect on the relative stiffness, even for values of I_{vl}/I_c lower than 0.5.

4- Conclusions

The following results are concluded from this research:

• The stiffness decreases by increasing the horizontal eccentricity.

• By choosing efficient values for the horizontal and vertical eccentricities, a large stiffness can be obtained, even more than the EBF with horizontal link between two diagonal braces.

• The effective and economic span for increasing the moment of inertia of the vertical links is about 50% of the moment of inertia of the columns. Such that, if the ratio of the moment inertia of the vertical links to the moment of inertia of the columns increases from 0.1 to 0.5, the stiffness increases about 15% and 60%, respectively in small and large eccentricities. While, if this ratio increase from 0.5 to 1.5, the stiffness increases about 2% and 10% in small and large eccentricities.

• The effect of the shear area of the vertical links on the relative stiffness of the frame is much more than the effect of the moment of inertia. However, the effective span for increasing the shear area of the vertical links is about 60% of the shear area of the beam. So that, if the ratio of the shear area of the vertical links to the shear area of the columns increases from 0.1 to 0.6, the stiffness increases about 140% and 85%, respectively in small and large eccentricities. While, if this ratio increase from 0.6 to 1.5, the stiffness increases about 22% and 15% in small and large eccentricities.

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Please cite this article using:
S., Sabouri-Ghomi, B., Saadati, “The Relative Stiffness of Steel Eccentric Braced Frame with Dual Vertical Links”. *Amirkabir J. Civil Eng.*, 49(1) (2017) 3-12.
DOI: 10.22060/ceej.2016.682