A Parametric Study on Seismic Behavior of One-Story Steel Frames Using Yielding Elements

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ABSTRACT :

In this research, behavior of structure based on energy concepts in concentric braced frame equipped with yielding elements has been studied. Released energy due to tectonic events will be absorbed by structural elements when an earthquake occurs, and cause destruction. In order to reduce structural damage, input energy must be dissipated. Yielding elements will act as fuse and absorb a great deal of earthquake input energy. Two one-story steel frames with different bay to height ratios (B/H<1 & B/H>1) are investigated in this article. First, by studying of the elastic behavior of system best location of ring with various percentages of openings is proposed. Then, different angles for ring elements connection are tested in each location. The stiffness ratio of steel frames to a similar moment frame without any braces is used as a criterion for comparing different locations and angles. After that, Nonlinear dynamic response of frame subjected to different ground motion records is obtained, and largest displacement and most base shear of different frames are compared. Finally, the ratio of dissipated energy by yielding elements to total entering energy of structure was calculated. This ratio shall assist designer toward better judgment for using this kind of yielding elements between energy dissipater systems.

KEYWORDS: Seismic Behavior, Yielding Damper, Steel Brace, Non-Linear Dynamic Analysis

1- INTRODUCTION:

To provide seismic requirements and reduce destruction in structural main elements in an earthquake, it's necessary to decrease absorbed energy to minimum available level. Concentrating input energy in dissipater elements is one of the methods formed on this basis. By using these elements we can prevent beams and columns from entering to nonlinear region, even in intensive earthquakes.

Eccentric braced system equipped with yielding elements is studied because of its easy implementation. In this system, yielding characteristic of steel centric ring is used to retrofit bracing performance. The ring is designed to show nonlinearity and absorb energy when severe lateral load occurs.

In this research, response of one-story frames with different dimensions was investigated. Performing parametric studies the best shape and location of yielding element is determined. Then, nonlinear dynamic response of frames in several earthquake records is showed. After that, the ratio of dissipated energy by yielding elements to total entering energy of structure is calculated.

2- BEHAVIOR OF YIELDING ELEMENT (YE):

Yielding ring as a passive energy dissipater was used at first in Rome University in 1989. It was part of a braced system that showed appropriate energy dissipation character [1].

Concentric braced frame (CBF) cannot dissipate energy very well because of brace buckling. Lateral load causes tension force in one brace and buckling of the other. In next cycle lateral load direction changes but buckled brace is not able to bear tension. While plastic deformation of brace has not any change, so the situation has not any change too.

Moment resistance frame (MRF) has good energy dissipation behavior, but it needs big sections for controlling story drifts. So, it's not an economical design. Also compressive design of braces is very expensive and makes the structure strict. Braced frames equipped with yielding elements (YE) is similar to frictional "Pall" system. The ring that should yield in earthquake has geometric similarity with main frame. As the yielding elements deforms nonlinearly in lateral load, it can reshape the buckled brace. The brace can withstand tension force in next cycle. So, the system has advantages of both braced and moment frames. Moreover, the destruction will be concentrated in yielding element and the main beams and columns will be safe [2].

3- MODEL PROPERTIES:

Two different frames with different dimensions were selected. They are shown in Figure 1. The frames carry 5 meter of ceiling load in transverse direction. Dead and Live loads are 550 kg/m^2 and 200 kg/m^2 sequentially. Structural system used is moment resistance frame and YE is attached to main frame by bracing elements.

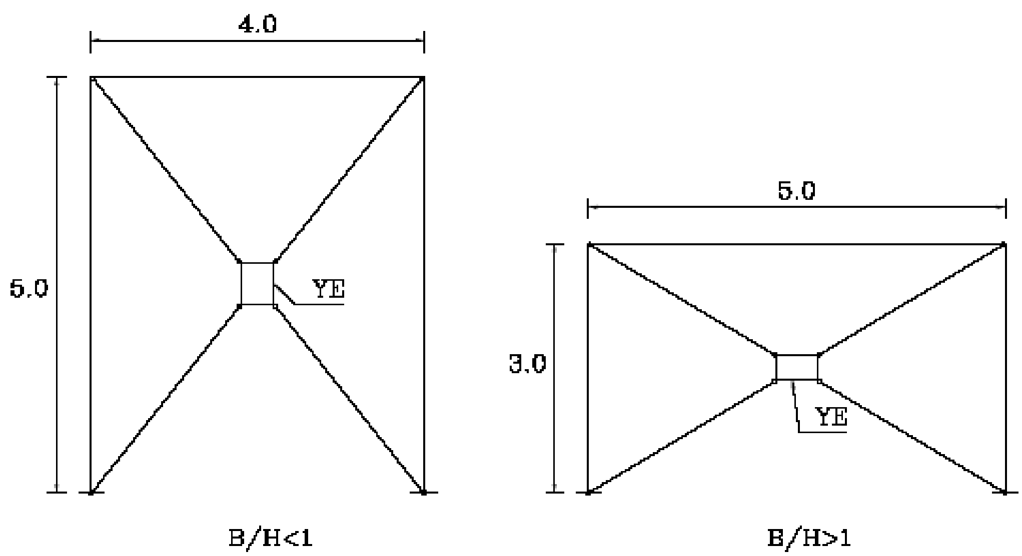

Figure 1- Studied Frames

It's necessary for YE to be proportional to main frame dimensions, otherwise it will be unstable and has no role in withstanding lateral load.

Seismic loads are determined based on Iranian Seismic Standard IRIS-2800, and base shear coefficient is calculated equal to 0.125 [3]. Preliminary design has been done according to AISC-ASD89 [4]. The results can be seen in table 1.

Table 1- Designed Sections

Frame	B/H<1	B/H>1
Column	IPB 180	IPB 180
Beam	IPB 160	IPB 200
Brace	BOX 40x40x4	BOX 40x40x4
Yielding Element	BOX 50x50x2	BOX 40x40x2

4-STATIC ANALYSIS:

4-1-Effect of YE location on frame stiffness:

Location of YE is determined by "b" and "h", "h" is the height of YE center to base of columns and "b" is its distance to right side column [5]. Locating the YE on right side or left side of frame won't effect on stiffness because of symmetry. To prevent formation of Plastic hinges in columns YE is not attached to them. Figure 2 shows the ring location in frame schematically. The stiffness of frame is normalized to a moment frame stiffness with the same dimensions. The results is demonstrated in figure 3 for B/H<1 frames and figure 4 for B/H>1. YE dimensions are 10,20,30 and 40 percent of main frame's.

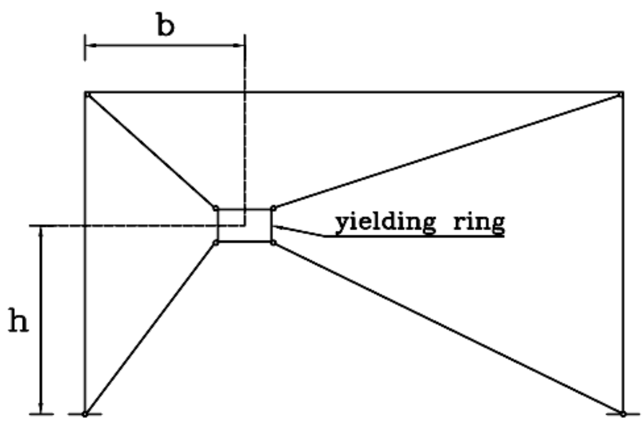

Figure 2- YE location

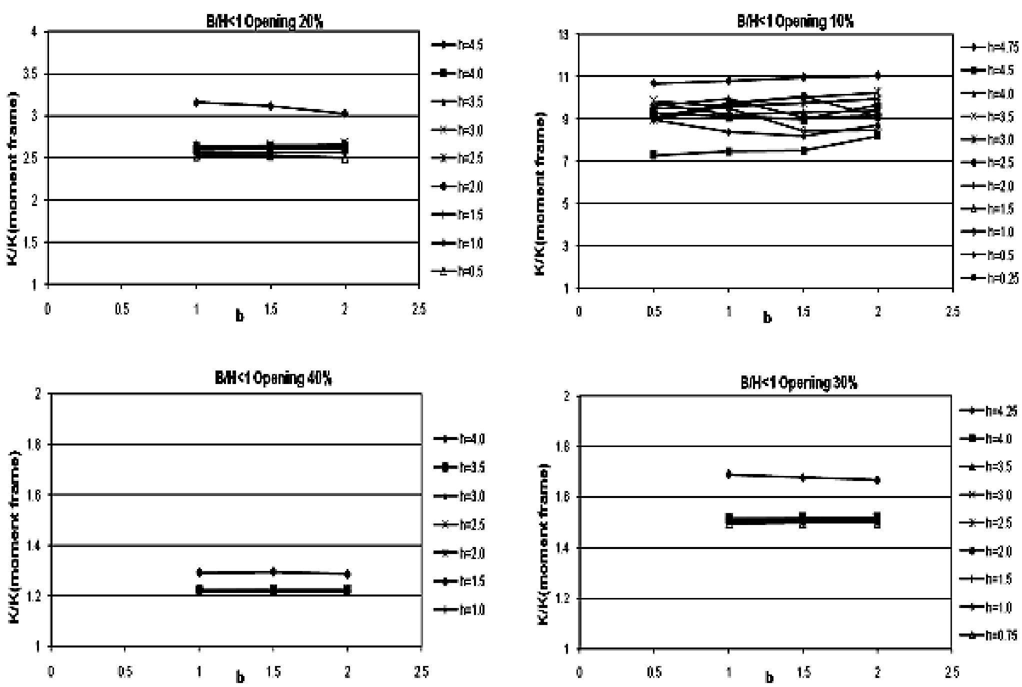

Figure 3- Normalized stiffness of frames B/H<1

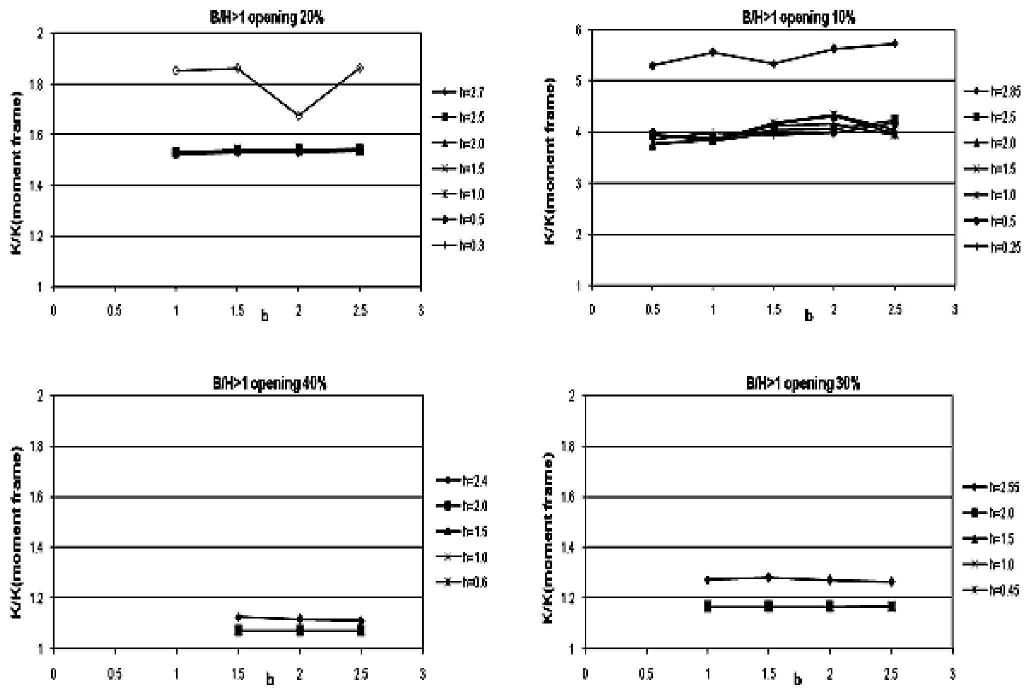

Figure 4- Normalized stiffness of frames B/H>1

4-2-Effect of element's angel on frame stiffness:

As it can be seen in figure 5, by decreasing connection angle we'll have a triangular YE. When the angle increases a trapezoidal YE is used instead of rectangular. It should be noted that these elements are attached to the top beam. Otherwise, the YE won't be stable. Normalized stiffness of frames is drawn in figures 6 and 7.

According to static analysis, most stiff frames are those in them YE is attached to the main beam. Locating of YE in other elevations has no noticeable effect on frame stiffness, and YE with smaller connection angle causes stiffer frame.

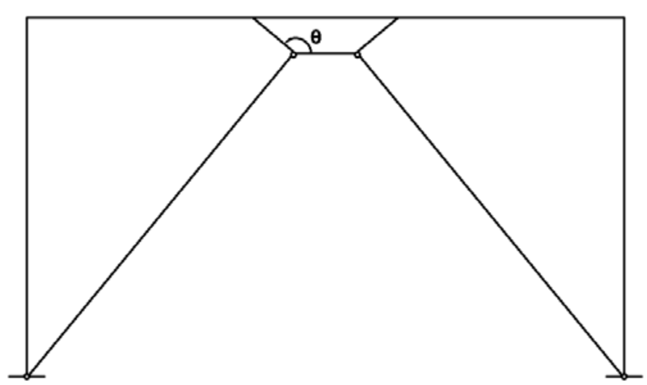

Figure 5- Connection angle

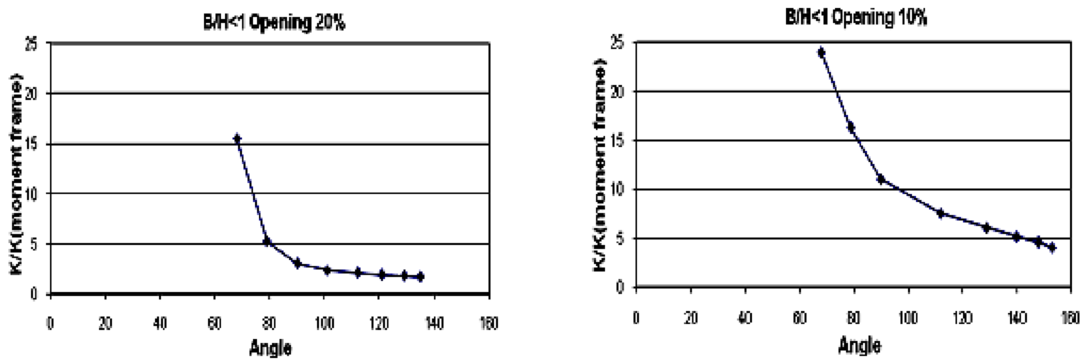

Figure 6- Normalized stiffness of frames B/H<1 with different connection angles

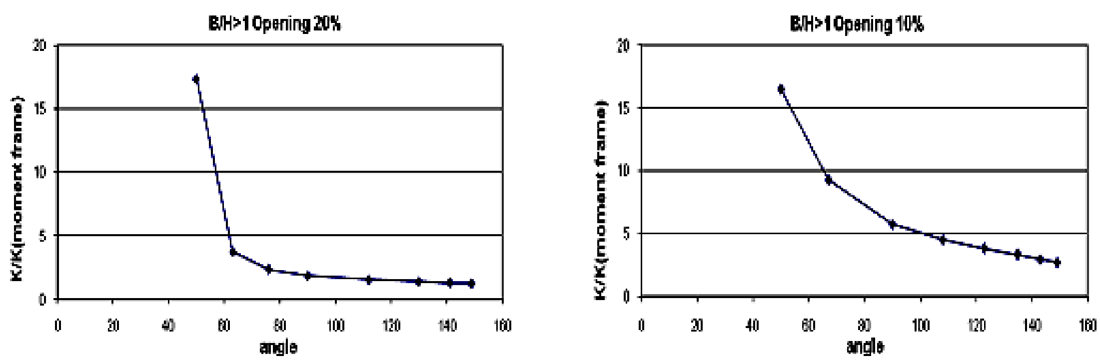

Figure 7- Normalized stiffness of frames B/H>1 with different connection angles

5-NONLINEAR DYNAMIC ANALYSIS:

According to previous section, 4 different statuses for YE shape and location are selected. The models can be seen in figure 9. In model "a" rectangular YE is located in the middle of frame. In "b", "c" and "d" rectangular, triangular and trapezoidal YE is attached to the middle of main beam.

Flexural behavior of steel is determined by a bi-linear diagram in figure 8. Secondary line slope is 3% of preliminary one.

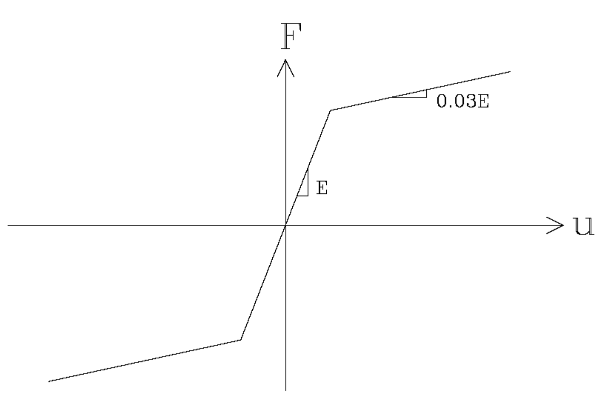

Figure 8- Flexural behavior of steel

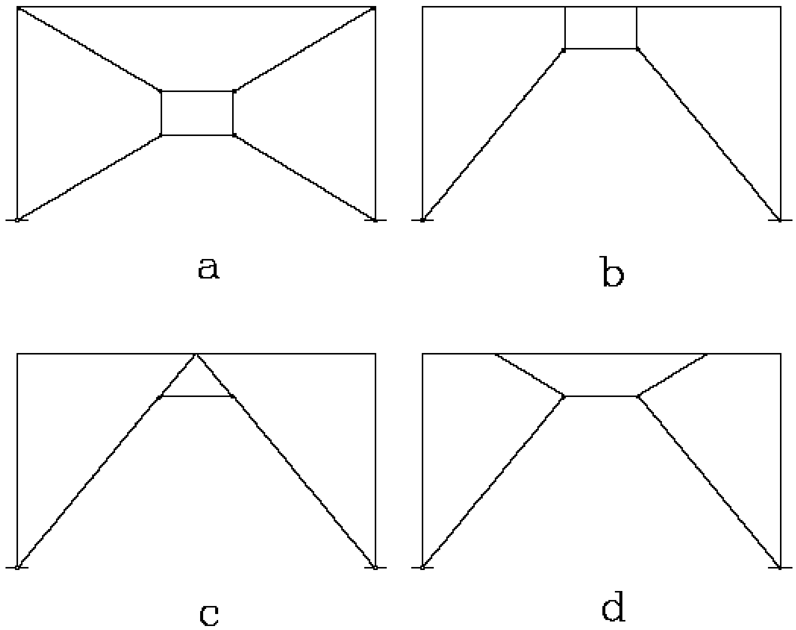

Figure 9- Different models for Nonlinear Dynamic Analysis

Models are analyzed for 2 different earthquake records: El Centro(1940) and Northridge(1994) [6]. The records PGA are scaled to 0.35g and 50 seconds of each record is utilized. Maximum displacement and base shear of models in different earthquakes are shown in figures 10,11,12 and 13. For better comparison each quantity in normalized with its similar quantity in moment resisting frame.

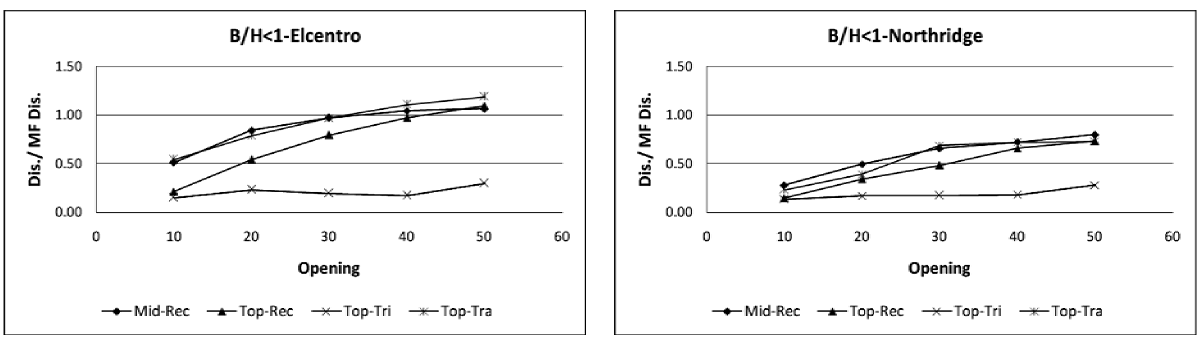

Figure 10- Normalized Displacement of B/H<1 frames

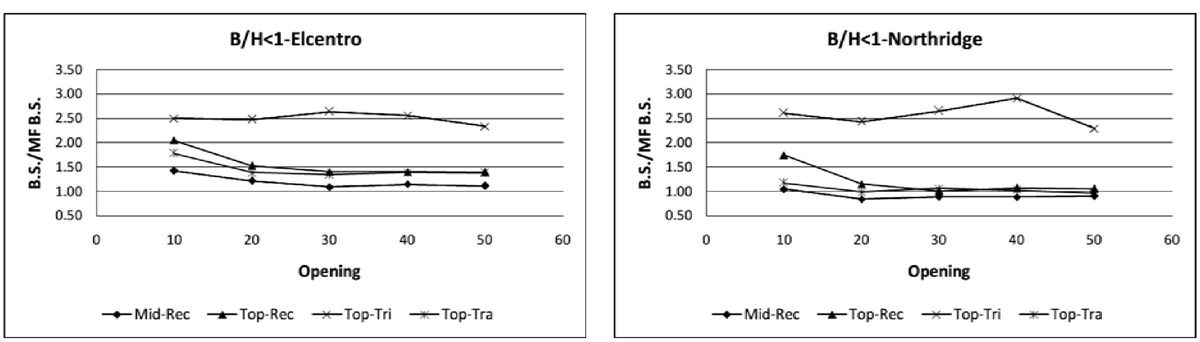

Figure 11- Normalized Base Shear of B/H<1 frames

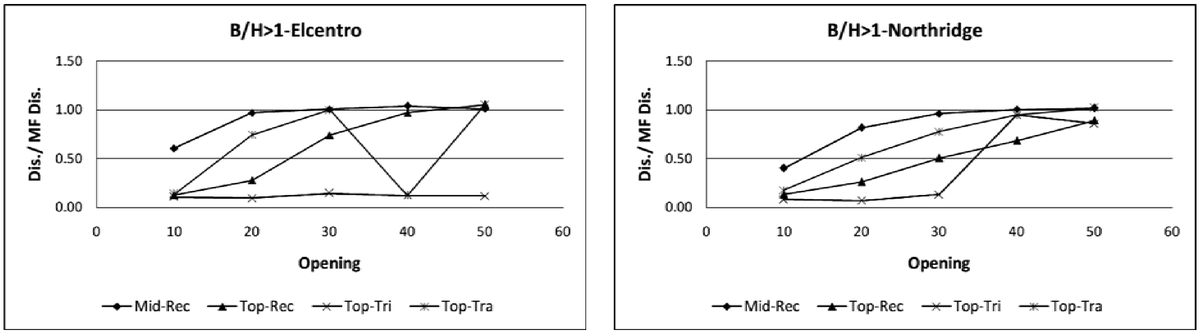

Figure 12- Normalized Displacement of B/H>1 frames

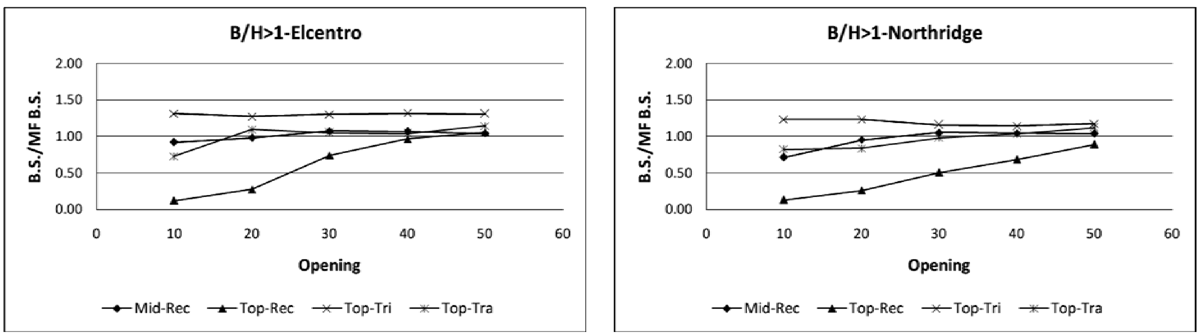

Figure 13- Normalized Base Shear of B/H>1 frames

6-NONLINEAR STRAIN ENERGY:

Energy balance in a structure is as Eqn. 6.1:

$$E_I = E_K + E_S + E_H + E_\xi \tag{6.1}$$

In this equation E_I is input energy, or the work done by base shear because of foundation displacement. E_K is kinematical energy, E_S is elastic strain energy, E_H is nonlinear strain energy or hysteretic energy and E_ξ is dissipated energy by viscous damping [7].

Rate of hysteretic energy is demonstration of nonlinear behavior of YE in an earthquake. More ratio of this energy, less kinematical and elastic strain energies are in structure. It means that by concentrating nonlinearity in YE, we can dissipate a great deal of input energy. For better understanding, the ratio of hysteretic to input energy is shown in figures 14 and 15.

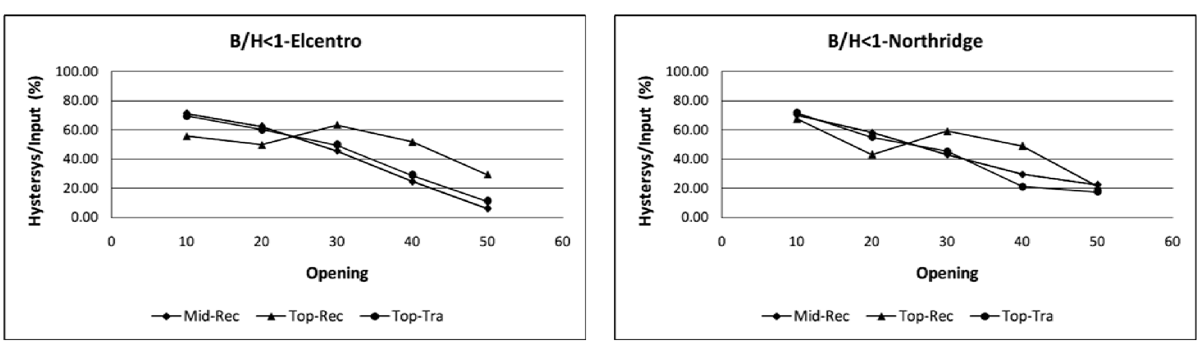

Figure 14- Hysteretic to Input Energy Ratio for B/H<1 frames

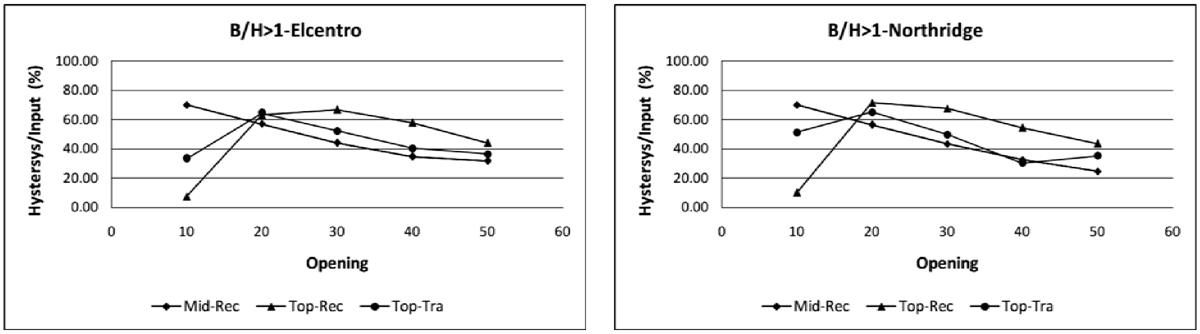

Figure 15- Hysteretic to Input Energy Ratio for B/H>1 frames

As it can be seen in previous figures, the most ratio of energy dissipation in the form of hysteretic energy for cases "a" and "b" is for YE with 10 percent of main frame dimensions. In these frames approximately 70 percent of input energy is dissipated. Optimum dimension for cases d and e is 20-30 and 10-20 percent of main frame dimensions sequentially. Energy dissipation in case "d" is zero so, triangular shape is not recommended.

7- REMARKS ON THE RESULTS:

1- Attaching the YE to top beam of frame will make it more stiff. But, other elevations have no noticeable effect on stiffness. Changes of frame behavior because of YE movement in width of frame are not significant.
2- Smaller the angle of connection in YE attached to top beam, Stiffer the frame. But trapezoidal YE has more ductility than triangular one.
3- Increasing the size of YE will decrease the stiffness so, the frame will have greater displacement and smaller base shear. Also the role of YE in bearing lateral load will decrease if the dimensions increase.
4- Optimum dimension for different cases of YE shape are as below:
   Rectangular YE in middle of frame: 10 percent of main frame.
   Rectangular YE attached to top beam: 20-30 percent of main frame.
   Trapezoidal YE attached to top beam: 10-20 percent of main frame.

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