

THE INFLUENCES OF THE DIFFERENT PGA'S AND HEIGHTS OF STRUCTURES ON STEEL BRACED FRAME SYSTEMS EQUIPPED WITH ADAS DAMPERS

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ABSTRACT

The behavior of braced steel frame structures is of special importance due to its extensive use. Also the applications of active and semi-active control systems have increased significantly due to their benefits in obtaining better seismic performance. The main purpose of this paper is to determine the behavior of structures equipped with yielding dampers (ADAS), located in far fields based on energy concepts. In order to optimize their seismic behavior, the codes and solutions are also presented. Three cases with five, ten and fifteen –story four-bay Concentric Braced Frames (CBF) with and without ADAS were selected. The nonlinear analysis is performed using the "Perform 3D V.4" software and the conclusions are drawn upon energy criterion. Finally, to increase the energy damping ability and reduce the destructive effects in structures on an earthquake event, so that a great amount of induced energy is damped and destruction of the structure is prevented as much as possible by using ADAS dampers.

Keywords: *Yielding Dampers (ADAS); Steel Braced Frame, Energy Dissipation Devices.*

1. INTRODUCTION

Development and subsequent implementation of modern protective systems, including those involving passive energy dissipation, the entire structural engineering discipline has changed a lot. Various energy dissipation devices such as modifying rigidities, masses, dampings or shapes are used and also the ductile structure is capable of absorbing forces to control the structural vibrations induced by earthquakes or wind excitations. In general, structural control devices can be divided into three classes: passive control, active control and semi-active control [1]. An active control device is known as a system which typically requires a large power source for operation of actuators which supply control forces to the structure. A semi active control system is similar to the active control systems but the external energy requirements are orders of magnitude smaller than typical active control systems [1-3]. A passive control system is defined as a system which does not requires an external power source for vibration response. Using energy dissipating devices in earthquake engineering has two important aspects in the applications, one of which is having a stable and sufficiently large dissipation capacity capable of controlling the earthquake response of the structure, and the other is having a representative model of its cyclic behavior. Different devices have been developed based on the use of low-yield metals with triangular and hourglass shapes [4-7]. These shapes are selected to spread yielding throughout the device, thus increasing the work dissipated internally by the structure. Among the best known devices are the patented added damping and stiffness device (ADAS) and variations such as the TADAS [5, 6] and Honeycomb damper [7]. The effectiveness of steel devices in reducing the earthquake response of structures has been shown experimentally in the past [4, 5]. As an example, ADAS devices have been used in the seismic retrofit of several structures in Mexico City [8]. Plasticity in low-yield metals satisfies the first condition as long as geometric effects due to large deformations in the device are not significant. On the other hand, several models of increasing accuracy have been proposed to represent the cyclic behavior of steel dampers subject to small deformations [5, 9-16].

This study mainly focuses on the effects of using ADAS devices and discussing on basic concepts of energy. To show the effects of ADAS devices when severe earthquakes occur, three cases with five, ten and fifteen –story four-bay Concentric Braced Frames equipped with and with ADAS devices have been considered to demonstrate the performance of their usage. The resulting detail and arrangement of typical ADAS devices are shown in figure 1.

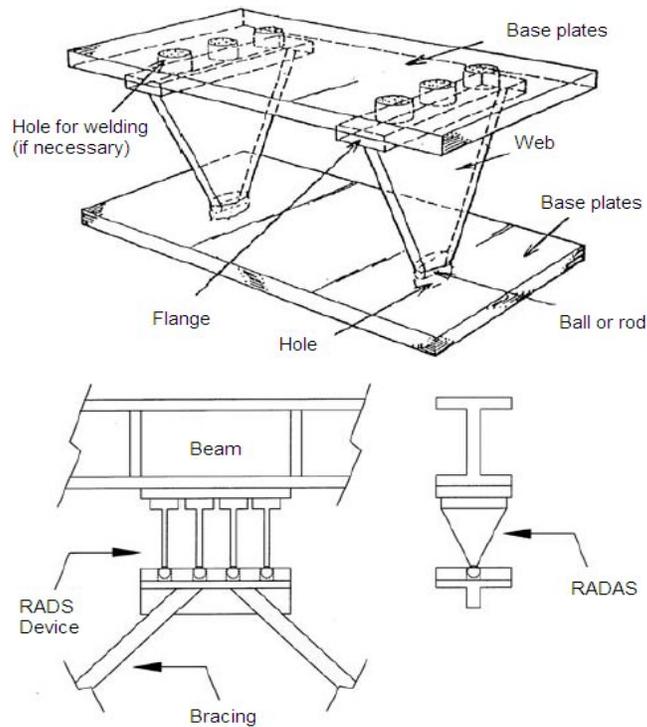


Figure 1. Arrangement of ADAS devices

2. ADAS DESIGNING PROCEDURE

2.1 Characteristics of ADAS devices

Experimental studies illustrate that the ADAS devices have nonlinear behavior under rush ground motions Tasi *et al* [13]. In order to simulate the seismic behavior of ADAS devices, a bilinear behavior between shear force and relative displacement is concluded. Thus, the ADAS devices bearable forces are given as

$$F_R = k' \delta_y + ak'(\delta_R - \delta_y), \tag{1}$$

where a is an unknown coefficient to be determined from the experimental data, K' is defined as the elastic stiffness of the ADAS devices and δ_R and δ_y represent the maximum relative displacement and yield displacement of the ADAS devices, respectively (see figure 2).

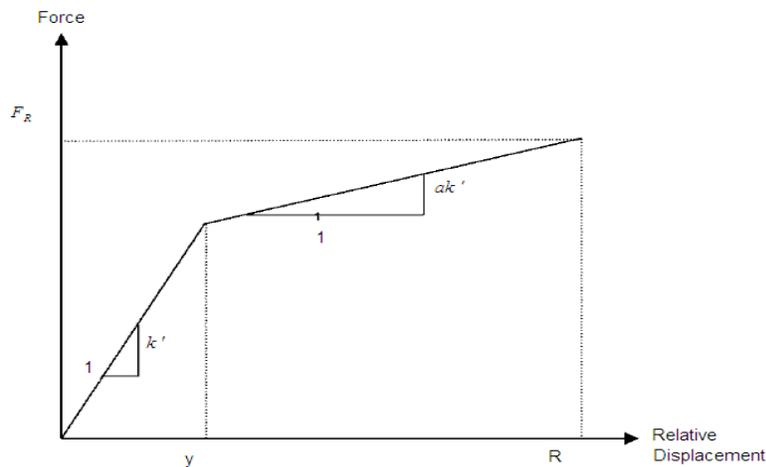


Figure 2. The relationship between force and relative displacement of ADAS

The ADAS devices provide reliable energy dissipation as they possess stable hysteresis loops through the yielding of steel plates. To achieve the aforementioned goal, it is imperative to choose a reasonable and acceptable ductility ratio range. The ductility ratio μ is defined as;

$$\mu = \frac{\delta_R}{\delta_y} \tag{2}$$

Let N represent the number of steel plates and K represent the stiffness of a steel plate. We have $K' = NK$. Substitution of Eq. (2) into Eq.(1) leads to

$$F_R = k' \delta_y + ak'(\mu \delta_y - \delta_y) = k' \delta_y (1 + a\mu - a) = KN \delta_y (1 + a\mu - a) \tag{3}$$

In accordance with the geometric shape of the steel plates, the stiffness of a steel plate, K can be determined; for example,

$$K = \frac{EBT^3}{6H^3} \text{ (Triangular - shape steel plate) } \tag{4}$$

and

$$K = \frac{2EBT^3}{3H^3} \text{ (X - shape steel plate) } \tag{5}$$

where E represents the elastic modulus of steel, and B , T and H indicate the base width, thickness and height of the steel plates, respectively.

2.2 Seismic forces and the effects of ADAS device design

The bracing members are considered rigid in stiffness when designing a building with damping devices. The reactive forces due to seismic impact on the building mainly include column shear forces and ADAS-absorbed forces (F_C and F_R in figure 3). The ADAS devices are designed to be able to absorb impact to keep the column shear forces less than the designed column shear forces at any time. Generally, ADAS devices are designed after a Concentric Braced Frames has been designed to meet the seismic building provisions. Let F_T be the maximum story shear forces of structures without ADAS devices on each story during earthquakes, F_D be the designed column shear forces and F_R represent the resistant forces of ADAS dampers that we design. If $F_T > F_D$, the goal of using the dampers is to absorb $F_T - F_D$ so that F_C will not exceed F_C during the earthquake. The above implies

$$F_R = F_T - F_D \tag{6}$$

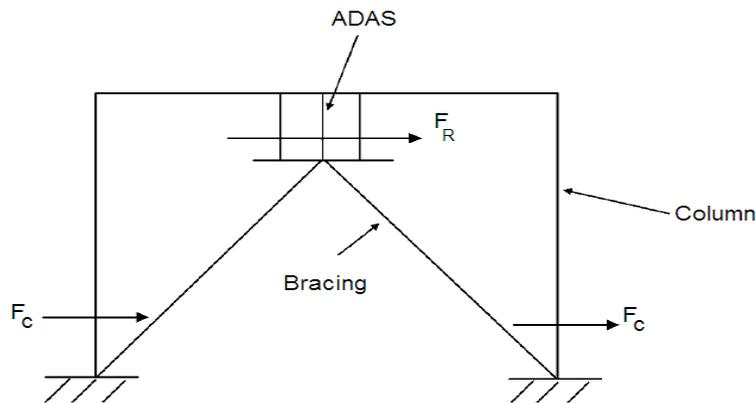


Figure 3. Shear force distributions of structures with ADAS during earthquake

Further, in Eq.(3), we use the designed ductility ratio μ_d instead of the resulting ductility ratio μ when N plates are used. Then, Eq.(5) leads to the number of steel plates for the ADAS devices to achieve the above goal:

$$N = \frac{F_T - F_D}{KN \delta_y (1 + a\mu - a)} \quad (7)$$

3. STUDY ON THE EFFECTS OF THE ENERGY DISSIPATING SYSTEMS

In order to show the effectiveness of the damper in this study attempt has been made to analyze the same structure without any dampers. Three cases with five, ten and fifteen –story four-bay Concentric Braced Frames, with and without ADAS (see figure8) devices were selected to illustrate the efficiency of using this kind of energy dissipative systems. The frames were designed prior to this study in accordance with Uniform Building Code 97 requirements, based upon the static analysis using the criteria tabulated in table 1.

Table 1. Analysis Criteria

Structure Type	Seismic Zone	Soil Type	Seismic Source	Distance from Fault
Concentric Braced Frame	Four	S_c	A	10 km (7.5 miles)

The Poisson's ratio and elastic modulus for the structure are equal to 0.3 and 2.0×10^8 kPa (2.9×10^4 ksi), respectively. The ADAS devices are fabricated on each floor and are supported by chevron bracing. The value of a in Eq. (1) is considered to be 0.12, and the range of the ductility ratios for the ADAS dampers is controlled between 3 and 5.

Table2. The properties of dampers

Width	height	thickness
12.7 cm	8.0 cm	3.26

The ADAS devices lower 80 per cent of the column shear forces using this procedure when the whole system is subjected to Imperial Valley Earthquake ground movements. Nonlinear time history analysis involves the computation of dynamic response at each time increment with due consideration given to the inelasticity in members. Hysteretic energy under cyclic loading is evaluated and tabulated. During strong and mediocre earthquakes, structures go into plastic range. Therefore, we have to use a nonlinear analysis. For this purpose, numerical simulations were carried out by Perform 3D.V4 software. Beams and columns were modeled as beam-column elements with a strain hardening of 3%. Bracings are considered as a truss-element that have capability of yielding in tension and buckling in compression and have a strain hardening of 3%. For modeling ADAS we used an equivalent prismatic beam. The mass of structure concentrated in the joints and distributed loads on the beams are applied as fixed end moments in end joints of beams. Other parameters are chosen as suggested in Perform 3D.V4 software manual. For numerical simulations, accelerograms related to horizontal component of the Imperial Valley (PGA=0.4g), (PGA=0.6g), (PGA=0.8g) are used.

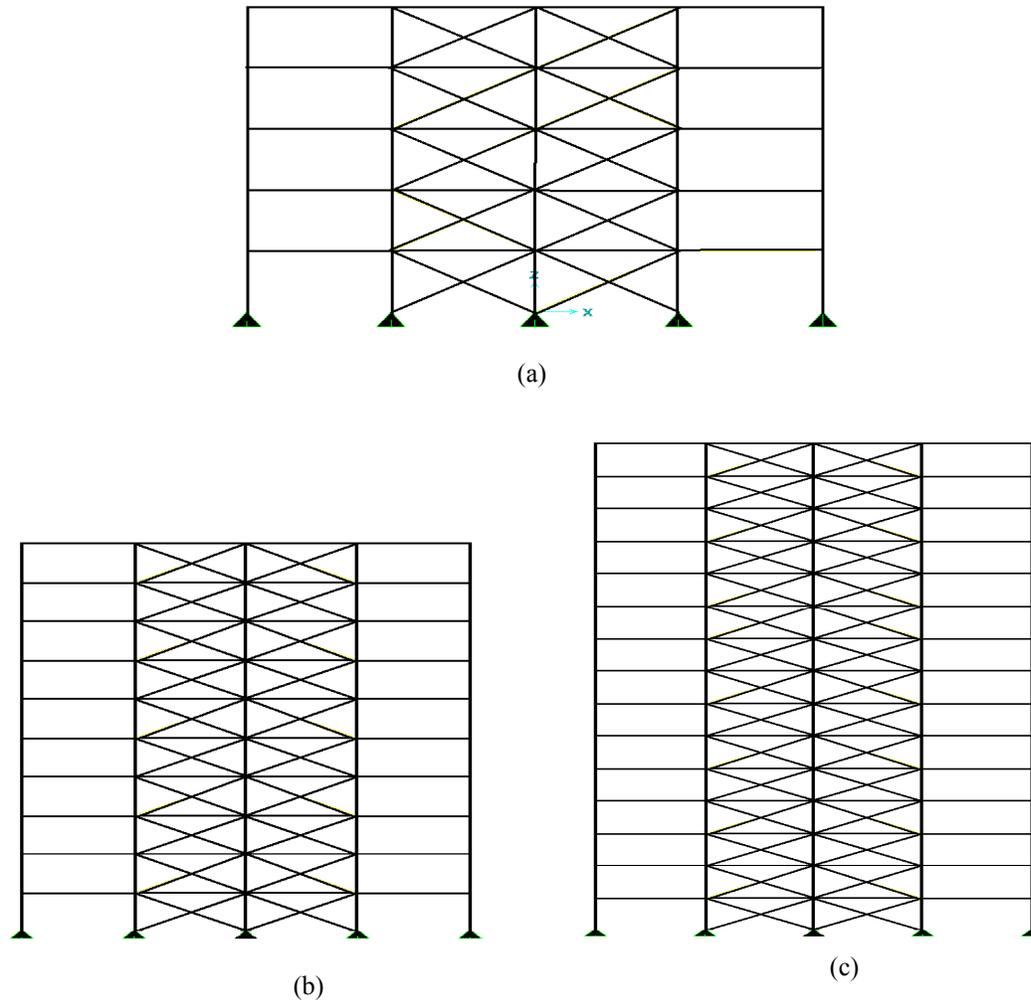


Figure.4. Different studied cases. (a) 5-story building (b) 10-story building (c) 15-story building

4. RESULTS AND DISCUSSIONS

Table 3 and figure 5 illustrate the amount of the Hysteretic energy for the case of Imperial Valley for both ADAS and CBF systems under different PGAs for 5, 10 and 15 - 4bay CBF and ADAS systems. The effects of the increase in the height of the structure on the input Hysteretic energy are depicted in figure 6. As it is shown in this figure, as the height of the structure increases, the values of Hysteretic energy for both systems are decreased and the decrease rate in ADAS system is larger than that in CBF. The influences of the variations of PGA of the structures on the input Hysteretic energy are illustrated in figures 7 and 8. As shown in these figures, the value of the Hysteretic energy is increased by adding to the PGA. This increase is larger for the ADAS system than for CBF.

Table 3. Calculated Hysteretic energies for different PGAs

Earthquake	Number of Bay	PGA	5 STORY		10 STORY		15 STORY	
			ADAS	CBF	ADAS	CBF	ADAS	CBF
Imperial Valley	4 BaY	0.4g	0.17	0.00	0.63	0.00	0.01	0.00
		0.6g	0.33	0.02	0.15	0.00	0.06	0.01
		0.8g	0.51	0.13	0.28	0.05	0.15	0.12

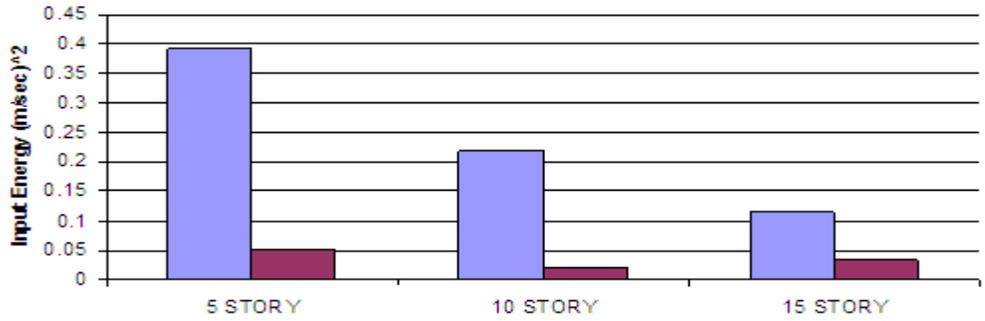


Figure 5. Comparison of Hysteretic energies for different considered buildings

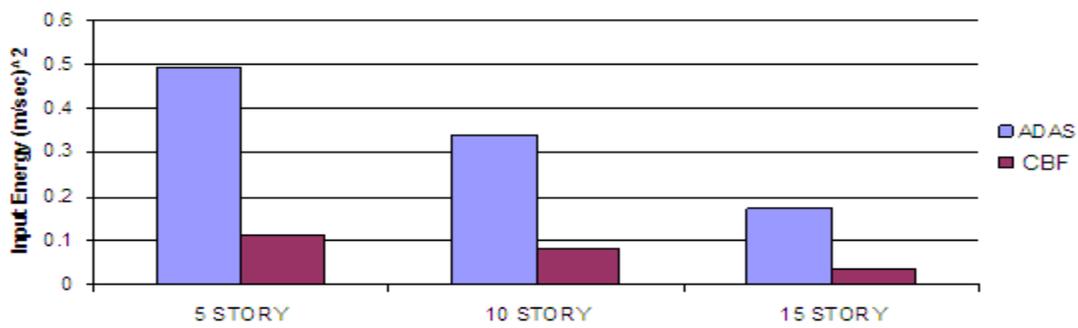


Figure 6. Effects of the number of building stories on Hysteretic energy

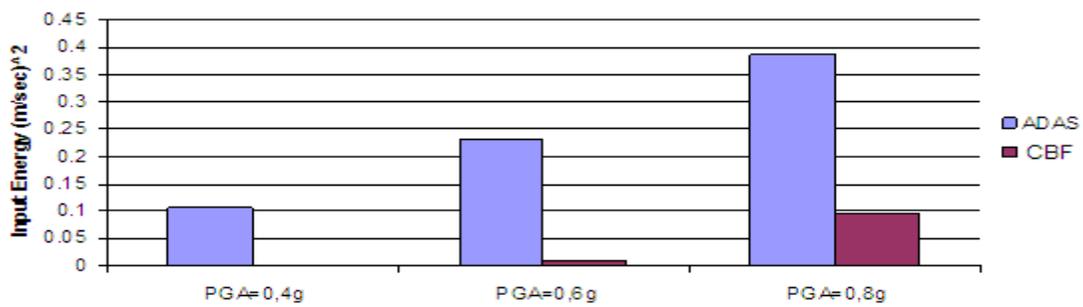


Figure 7. The influence of different PGA's on Hysteretic energy

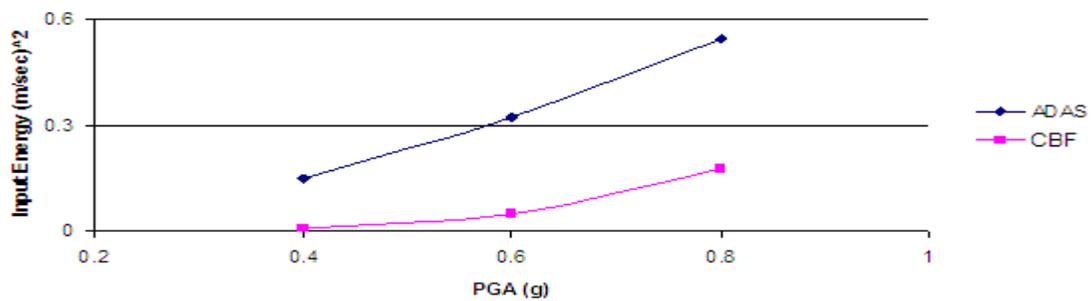


Figure 8. The influence of different PGAs on Hysteretic energy

5. CONCLUSIONS

The current study shows the difference of building behaviors with and without damper during earthquake vibrations. This study implements the commercial package Perform 3D.V4, information regarding the seismic hazard, passive control system and nonlinear structural response. The energy dissipation device significantly increases the resistance of the structure components to the dynamic loads and they are effective in reducing the seismic response of the structures. The benefits of the energy dissipaters have been clearly demonstrated by these comparative data and the improvement in performance of structure during earthquake excitation have been proved. In addition, the considerable effect of the ADAS dampers in absorbing Hysteretic energy is illustrated. The passive control system absorbs the vibrations automatically without the need of an electrically controlled system. Passive control systems are generally low in cost and effective for support of buildings subjected to dynamic vibrations. It will allow practicing engineers to design and use cost-effective seismic dampers in the preliminary design phase effectively, letting them explore the cost factors by comparing different building seismic performance objectives throughout design.

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