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Seismic behavior of concrete structures equipped with ADAS devices

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Abstract. The added damping and stiffness dampers can be improved the seismic behavior of the concrete structures, and they can be reduced the internal forces in the bracing members, columns and the other structural members. The usefulness of supplementary energy dissipation devices is now quite well-known in earthquake structural engineering for reducing the earthquake-induced response of structural systems. The seismic behavior of structures with supplemental ADAS devices is concerned in this study. A simple method for modeling and analysis of X-braced frames equipped by these dampers is proposed. Braced steel frames with dampers and without dampers are considered for time-history dynamic analysis, and some parameters such as: base shear, axial forces of the columns and the bracing, drift of stories etc. for two different cases are compared. In the entire analyzes, the structure with damper has been shown the better performance and the more suitable seismic behavior than the structure without damper.

Key words. Rehabilitation, ADAS damper, concrete structure, energy dissipation.

1. Introduction

Today, many researchers in the world in order to control structural vibrations against the earthquake force they have focused on input energy dissipation systems which also focused on non-linear deformation during earthquake in these systems which help the repair and optimization of structures [1]. Dampers belong to the category of passive control equipment's and increase the structure damping and also control the response and the reduction of the seismic need and their most conspicuous feature is the ease of control and manufacturing due to the lack of high complexity in form and manufacturing technology and also the ease of changing these kinds of dampers after a severe earthquake is because of their damage [2]. The use of energy absorption dampers in structure seismic control during the earthquake has been noted for years [3]. The yielding metal dampers on self-focusing damage, other structural components kept in the elastic zone and reduce the structural dynamic responses [4],and they are also adequate equipment's for seismic resisting of struc-

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tures. And with low expenses and high-speed performance, the seismic behavior of structures will be [5]. Since the 1990s, many mechanisms have been introduced, fabricated and tested as a yielding metal damper [6], and some of them like ADAS and TADAS are commercial [7].

2. ADAS (Added Damping and Stiffness)

Added Damping and Stiffness (ADAS) elements are designed to dissipate energy thought the flexural yielding deformation of mild-steel plates. ADAS elements consist of multiple X-shaped mild steel plates configured in parallel between top and bottom boundary connections (Figs. 1, 2).The particular advantage of an X-plated is that, when deformed in double curvature, the plate deformation is uniform over its height, and when deformed into its plastic regime, the yielding will be distributed rectangular plate, when deformed plastically in double curvature, will yield only at its ends. This concentration is particularly undesirable both in.

This study mainly focuses on the effects of application of ADAS devices – discussing the basic concepts of energy. To show the effects and performance of ADAS devices when severe earthquakes occur, three cases consist of five, ten and fifteen-story Frames equipped with and without ADAS devices have been considered.

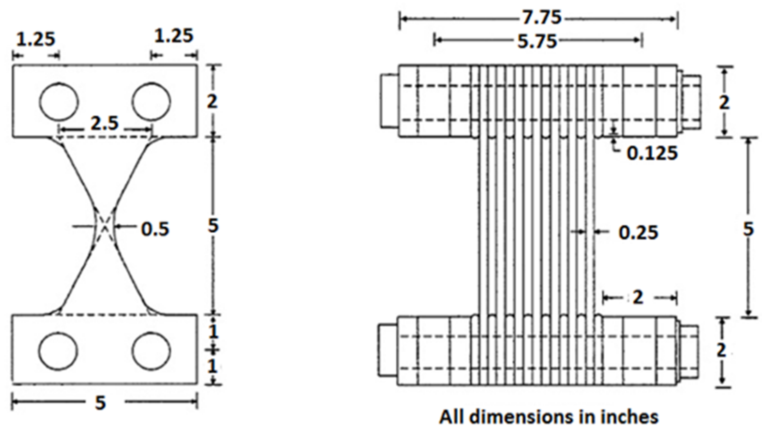

Fig. 1. Arrangement of ADAS devices

3. Modeling and analyses

3.1. Bare frame structures

Three buildings of five, ten and fifteen stories representing short, medium and long period structures are considered for the parametric study. Owing to the vertical and horizontal regularities of the buildings, only one of the inner frames of each structure is analyzed and designed. The buildings are assumed to be located in

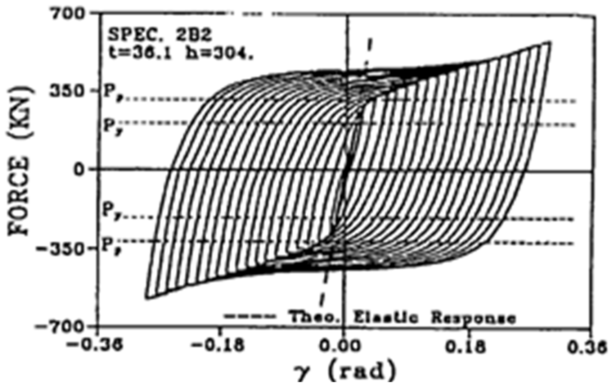

Fig. 2. Hysteretic behavior of ADAS device [7]

Los Angeles and with office occupancy. Similar design parameters and loads are considered for the three buildings.

The modulus of elasticity, yield stress and Poisson's ratio of the steel material are considered equal to 200 GPa, 345 MPa and 0.3, respectively.

The structures are loaded according to ASCE 7–10. Dead and live loads are assumed to be $5\,kN/m^2$ and $2.4\,kN/m^2$, respectively, for all stories. Seismic design is performed based on the equivalent lateral force analysis. In order to investigate behavior of frame in Fig. 3 and to clarify the application of designed damper in its seismic resisting, software studies have been used. Firstly, Fig. 3 frame was analyzed and designed by SAP2000 software. The frame has been modeled by this damper through Abaqus software, and has been analyzed through finite element.

4. Loads

The applied loads are the structure self-weight, and seismic loads based on seismic hazard analysis of the structure site. It is noteworthy that three ground motions were selected for seismic analyses based on source characteristics, source-to-site transmission path properties, and site conditions [7]. These ground motions are 1990 Rudbar (at Tabas station) as No. 01, 2003 Bam as No 02 and 1978 Tabas as No. 03. Time history of these ground motions are depicted in Fig. 4.

Different models were analyzed in order to involve usual cases encountered in practice. Their geometry and dimensions are as real and with no scale under different type of loading as illustrated in Table 1 and Figs. 5 and 6. After applying load on model the whole model has displacement in all body. But top of structure is a critical point that can be analyzed separately. In this study the top displacement of models have been studied too. For model top displacement has been illustrated in Fig. 5. Top point displacement have been illustrated for two points on the top of the structure, first top left corner and second top center corner.

Utilizing ADAS devices in the frame structures, for all the three frames, causes the oscillations after the main shocks of the earthquake to be damped much more

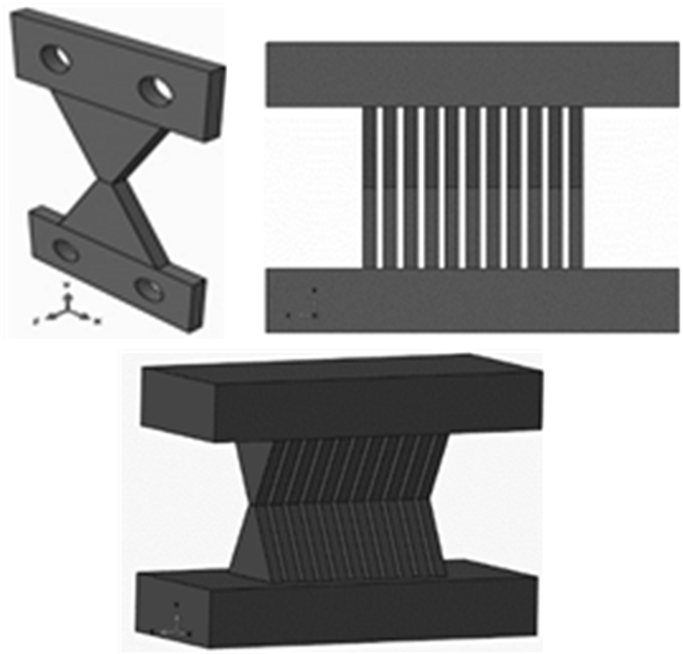

Fig. 3. Abaqus model of ADAS damper

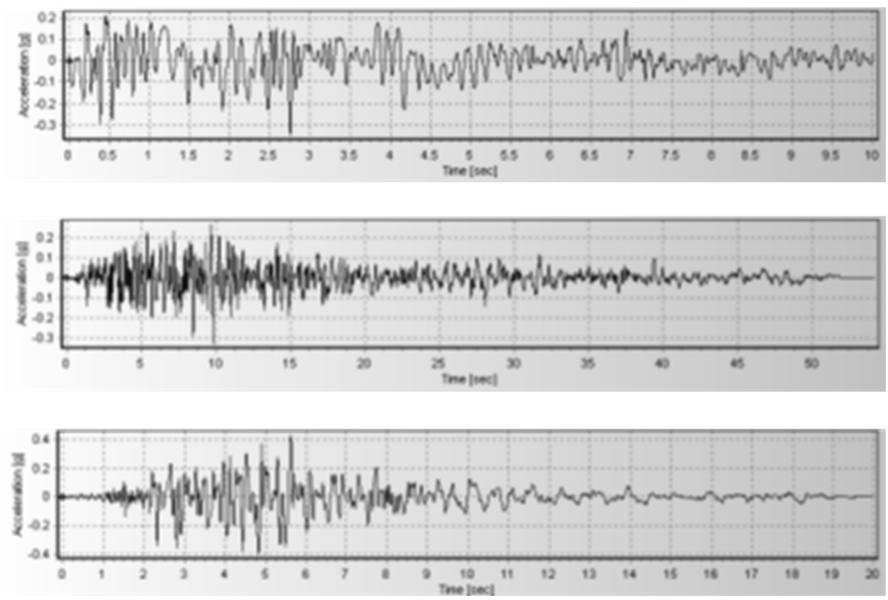

Fig. 4. Time history of ground motions in stream: top–Rudbar, middle–Bam and bottom–Tabas

quickly and reduces the residual displacement considerably.

Table 1- study models.

	Model Name	Top Displacement(cm)
5storey	M5-1	25
	M5-2	9
	M5-3	43
	M5-4	12
	M5-5	32
	M5-6	11
10storey	M10-1	34
	M10-2	12
	M10-3	38
	M10-4	20
	M10-5	43
	M10-6	27
15storey	M15-1	60
	M15-2	53
	M15-3	87
	M15-4	55
	M15-5	75
	M15-6	61

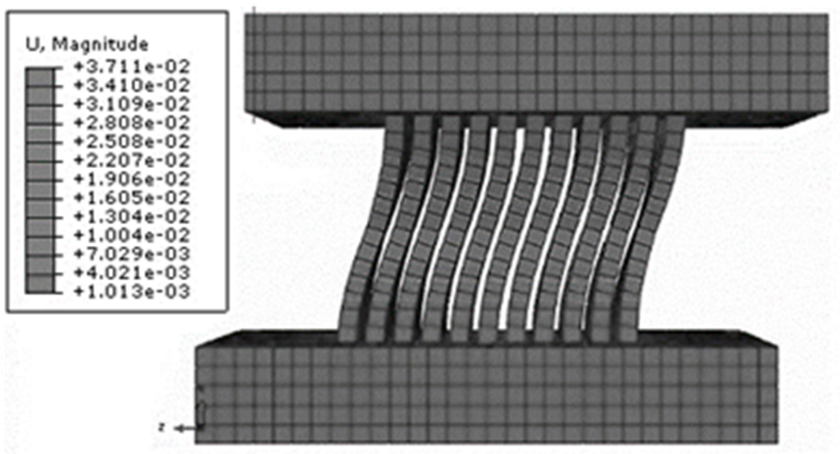

Fig. 5. Displacement in ADAS damper in model M15-6

The maximum tip displacement curves of the 15-story structure are mainly flat and even ascending in some intervals. This can be attributed to the higher natural period of the 15-story structure which is in the velocity-sensitive region of the spectrum. This means the reduced natural period of the 15-story structure due to added stiffness of ADAS leads to higher spectral acceleration, depending on frequency content, and makes the ADAS less effective in the 15-story structure. The other reason is the overall bending of the structure. The taller and slimmer a building is, the more it oscillates in overall bending mode, and the dampers effectiveness is reduced as a result.

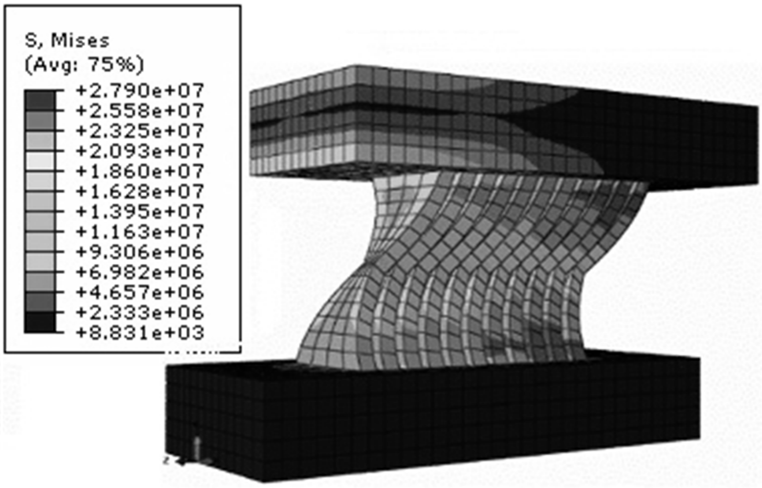

Fig. 6. Stress in ADAS damper in model M15-6

The values of retrofitting frames base shear with ADAS in short frames are between the values of moment frames. while with attention to graphs we aimed with increase of stories, value of frame shear with damper is less than of moment frame and this decrease is due to factors like capacity of energy absorption. Figures 5 and 6 show the stress and displacement counter in ADAS Damper in model M15-6. For ADAS's damper frames, nonlinear deflection was majority concentrated in ADAS device that cause to increase hysteresis energy absorption of structure without large deflect, also results signify lack of create large deflective in the members' of structure & due to the distribution of the displacement at structures height. Finally, Fig. 7 shows the Story Base Shear for 15-story structure.

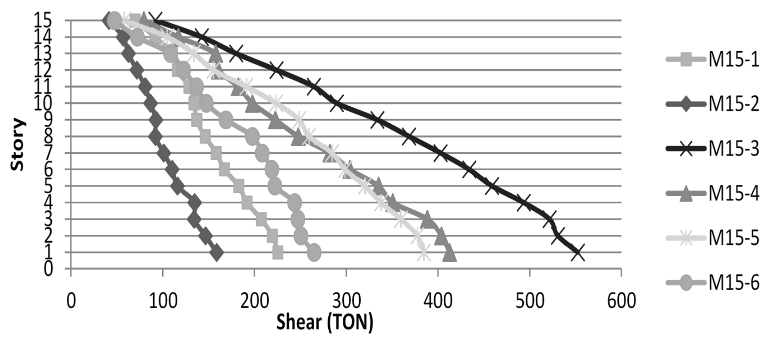

Fig.7. Story Base Shear for 15-story structure

5. Conclusion

Guidelines for implementing ADAS dampers in steel buildings were presented in this paper. 5-story, and 15-story steel moment resisting frames were designed without dampers first and then equipped with ADAS of different strength. The ADAS strength was selected based on the maximum allowable drift of each story. The responses of the frames without and with ADAS to three earthquake excitations, were investigated. The results of the study proved that ADAS are capable of significantly reducing the structural and nonstructural seismic damages and increasing the seismic reliability of structures. The inelastic energy absorbed by the main frames decreases quickly by using ADAS dampers. This translates to no damage or limited damage to the main frame. However, for the frames under MCE, there are some level of damage in some cases, especially for the 15-story frame. Maximum tip displacement is reduced by an average of 70.0 %, 69.4 % and 36.0 % in models with ADAS strength compared to bare frames, for the 5-story and 15-story frames. The ADAS are less effective in reducing seismic responses of the 15-story structure than the 5-story structures due to the higher natural period and the overall bending mode deformation of the taller building.

References

[1] T. T. Soong, G. F. Dargush: *Passive energy dissipation systems in structural engineering.* John Willey & Sons Ltd., New York, USA (1997).

[2] J. M. Kelly, R. I. Skinner, A. J. Heine: *Mechanisms of energy absorption in special devices for use in earthquake resistant structures.* Bulletin of N.Z. Society for Earthquake Engineering (NZSEE) *5* (1972), No. 3, 63–88.

[3] A. Whittaker, V. Bertero, J. Alonso, C. Thompson: *Earthquake simulator testing of steel plate added damping and stiffness elements.* Earthquake Engineering Research Center, University of California, Berkeley, CA, Report No. UCB/EERC – 89/02, (1989).

[4] R. D. Hanson, I. D. Aiken, D. K. Nims, P. J. Richter, R. E. Bachman, R.E: *State of the art and practice in seismic energy dissipation.* Seminar on Seismic Isolation, Passive Energy Dissipation and Active Control: Applied Technology Council, 11–12 March 1993, San Francisco, CA, Proceeding of ATC (Series) *17* (1993), No. 1, 68–79.

[5] S. F. Stiemer, W. G. Godden, J. M. Kelly: *Experimental behavior of spatial piping system with steel energy absorbers subjected to a simulated differential seismic input.* Earthquake Engineering Research Center, University of California, Berkeley, CA, Report No. UCB/EERC – 81/09, (1981).

[6] C. Xia, R. D. Hanson: *Influence of ADAS element parameters on building seismic response.* Journal of Structural Engineering *118* (1992), No. 7, 1903–1918.

[7] K. C. Tsai, H. W. Chen, C. P. Hong, Y. F. Su: *Design of steel triangular plate energy absorbers for seismic resistant construction.* Earthquake Spectra *9* (1993), No. 3, 505–528.

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