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Determining the Best Insertion Site of Fluid Viscous Dampers to Optimize and Reduce Incurredcosts in Adjacent Buildings

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Abstract

In the past decade, researchers developed the idea of connecting buildings with intelligent activated, semi-active and inactivated damper systemsreduce adjacent buildings response to wind and earthquake. One of the most important damper devices in non-active control is fluid viscous damper.Fluid dampers due to viscous fluidsshow high resistance. High resistance of viscous fluidsagainst the flow is the basicfunctionof fluid viscous dampers. Deformation speed a fluid viscous damper is proportional to the acted forces. Therefore the aim of this paper is to determine the insertion site of fluid viscous dampersto optimize and reduce the consuming costs in adjacent buildings. For this purpose, four different models of connected adjacent buildings with common and different shear stiffness in the software SAP 2000 has been modeled. This study shows that it is not necessarytwo adjacent buildings connected by a damper on all floors, but the less damper in appropriate selected locations can help reduce the earthquake response. And by placing the fluid viscous dampers in selected certainfloors provides more useful structural system for reducing the effects of earthquakes.

Keywords: non-active control, the adjacent buildings, viscous dampers, optimization

1. Introduction

Today, residential and commercial buildings and structures are significant proportion of the country and society. Simple buildings and single-story day by day due to population growth and lack of space are replaced by multi-storey buildings. Thus, today much attention has been paid to multi-storey buildings. In the past decadesthese buildings merely were designed to withstand static loads and weight of structures. However, these buildings arealso exposed to dynamic and lateral loads such as wind, wave, earthquake and the load of vehicles. Vibration motion in multi-storey structures caused by dynamic loads and may be dangerous for the security of structures. Therefore, for the security and safety of buildings in its lifespan these vibration motions should be reduced as much as possible. In general, the total size of displacement and partial lateral shifting of floors should be limited and the absolute acceleration of structures must also be minimum to comfort of building occupants is ensured. In the seismic design it is tried to increase the hardness of buildings, for example shear wall and bracing systems can be used for this purpose. With the rapid development of technology in the world, it seemsa greater need to secure multi-storey structures. Theextension of technology has increased the convenience and security expectations of buildings among people. Today's findings have suggested other alternatives to reduce the total size of displacement and partial lateral shifting of floors. Of these methods it can be referred the use of dampers, separators and mass dampers (Taylor & Constantine, 1998). Fluid viscous dampers act like shock absorbers of vehicles (Varnoteh et al., 2007). The dampers are formed with a cylinder containing a fluid, such as oil. Inside these cylinders a piston acts with a number of leaks that is connected to the piston rod. The dampers operate by piston moves inside the valves with viscous fluid damper. The shape and size of the holes inside the piston as well as the viscosity of the fluid used can affect the amount of energy and sustainable energy. Stresses and deformations of building during applying dynamic load by the dampers are reduced. Dampers with applying opposing forces to structural elements neutralize the inflicted force of them and depreciate it. If the damper not to be used, structural elements, especially columns highly are placed under stress and their stress will be maximum, as well as the displacement of them in earthquake will be high (Varnoteh et al., 2007). This advantage of fluid viscous dampers allows them to reduce the seismic response of adjacent buildings. Different control methods and systems for the control of adjacent structures against earthquakes have been done by scientists and engineers or are being done. Hasner et al. (1997) in a study examined the benefits of structural control in reducing unwanted vibration in buildings. They also proposed various control systems for this purpose.

Seto (1994) has introduced connecting the adjacent buildings as a practical way to protect and strengthen structures against dynamic loads. He has introduced different strategies for inactivated control systems for tall and short buildings.

Richards et al. (2006) in a study stated that the use of control systems for connected adjacent structures is a good way to protect flexible buildings. They also examined the influence of shape and compositionsof structures as well as the insertion siteof dampers in the performance of entire system. They also studied the efficiency of both activated and inactivated systems in the control of adjacent buildings.

Zhou and colleagues in 1999 in a study tested the seismic response of connected adjacent buildings by a damper under seismic movements. They observed that the earth acceleration during earthquake is an incidental process and random vibration algorithm used by computer programs to explore the new dampers system. They also suggested that the optimal characteristics of dampers are determined by parametric study.

Hadi and Owz (2009) in a study examined the importance of using fluid viscous dampers to improve the seismic behavior of adjacent structures. They found declines of the last floor displacement, acceleration and shear force response of adjacent structures during seismic stimulation. In their study adjacent structures had been connected in one direction by dampers.

Kim et al. (2006) studied the effect of installation of visco-elastic dampers (VED) in places like connecting building to the air bridge to reduce the seismic response of structures. In their research, parametric study was performed and firstly the system was examined with one degree of freedom connected fluid viscous damper. Dynamic Analysis was conducted in the frame of 5 floors and 25 floors. Their results indicate that the use of fluid viscous dampers in air bridges to reduce seismic response movementsis fruitful.

Mentioned studies show that inactivated, activated and semi-activated control systems, every day are becoming increasingly important to reduce the seismic response of connected adjacent buildings affected by seismic movements. In this article, determiningbest insertion site of fluid viscous dampers to optimize and reduce incurredcosts in adjacent buildings will also be examined.

By using the damper and during displacement and bending of columns maximum, the maximum damper force will be maximum (Varnoteh et al., 2007). Fluid viscous dampers due to their very appropriate function are preferred to other techniques. To connection the dampers to the building, there are different methods. Fluid dampers connecting in adjacent buildings have changed in recent years.

2. The Characteristics of Studied Models

In this paper, two fluid viscous dampers that will be shown with D1 and D2 initials will be used. Xu and Colleagues (1999) in a study determined the amount of damping coefficient for adjacent buildings about$1 \times 10^6 \mathrm{N} \times \mathrm{s/m}$. In this paper, the damping coefficient in two basic models, are considered $\mathrm{c_d} = 0.25 \times 10^6 \mathrm{N} \times s/m$ and $\mathrm{c_d} = 0.85 \times 10^6 \mathrm{N} \times s/m$, respectively. Table 1 shows the size of rows and columns in the mentioned sample buildings.

Table 1. The dimensions of the rows and columns in adjacent buildings on both models

Building B			Building A			Example
Row Dimensions(mm)	*row width* (mm)	*row height* (mm)	*Row Dimensions*(mm)	*row width* (mm)	*row height* (mm)	*number*
500X300	250	500	600X300	250	600	1a
500X300	250	500	500X300	250	500	1b
500X300	250	500	600X300	250	600	2a
500X300	250	500	500X300	250	500	2b
600X300	300	500	700X300	300	600	3a
600X300	300	500	600X300	300	500	3b
600X300	300	500	700X300	300	600	4a
600X300	300	500	600X300	300	500	4b

Figure 1 Show schematic plan of rows and columns in the adjacent buildings and the installation site of dampers

for both models.

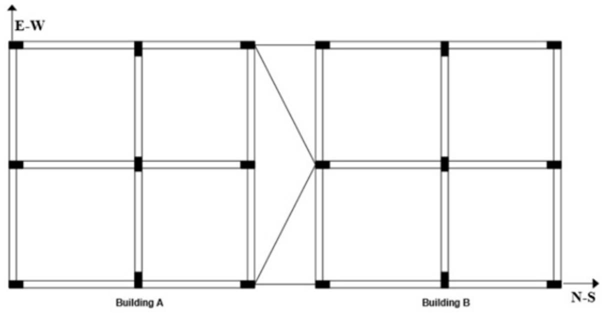

Figure 1. Schematic diagram of rows and columns plan in the connected adjacent buildings for both models

3. The Characteristics of Models

In this paper, four different models of different connected adjacent buildings with the same shear stiffness in the software SAP 2000 have been modeled. The aim of this chapter is to provide different examples of connected adjacent buildings to the fluid viscous dampers performance to be evaluated. In all examples damping coefficient is assumed to be constant.

The first model is two 5-storey buildingswhichconsist of two reinforced concrete building. Both building have floors with the same height. The first example has two parts: In the building A from 1a model, the stiffness of columns is more than building B, while in model 1b dynamic characteristics in both buildingsisquitethe same. The purpose of this model (Figure 2A) is to evaluate the efficiency ofviscous dampers in buildings with the same height. Second model is a 10-storey building and an adjacent 5-storey building. In this model, mass and damping coefficient are similar but the height of adjacent buildings is different. In this model, two parts, one with considering a different hardness (stiffness) and the other with the same hardness (stiffness) have been used.

In the third model a 20-story building and a 10-storey building have been considered. In this example, shear stiffness and mass of buildings is different. The purpose of this example is evaluation of the efficiency of dampers in connected buildings interms of different dynamic features and height. In the fourth model, two 20-storey reinforced concrete buildings have been modeled. In this example the hardness (stiffness) of any building is different.

The damping coefficient of structurein software SAP 2000 is automatically calculated by the following equation:

$$[C] = diag(2M\xi\omega) \tag{1}$$

In this equation, [C] is attenuation module matrix, and M, ξ and ω respectively are mass, modulus, damping ratio and natural frequency. Different dimensions of the row and column are used to examine the effectiveness of dampers. Using these models, a comprehensive study on the impact of fluid viscous dampers on adjacent buildings with different degrees of freedom under the impact of seismic movements is performed. In this model roof loads are transferred into rows uniformly. In the model 1a while the load floor in both buildings A and B are similar, the mass of building B and building A is slightly different because of the difference in the size of rows and columns. Table 2 shows the details of design and the specification of the materials used in the simulation.

Table 2. The information of loads and materials used in the models design

Amount	Description
4.0 KN/m2	Live load
2	Soil type
300 MPa	Concrete Compressive strength
27386 N/mm2	Concrete elastic modulus
0.12 m	Slab height

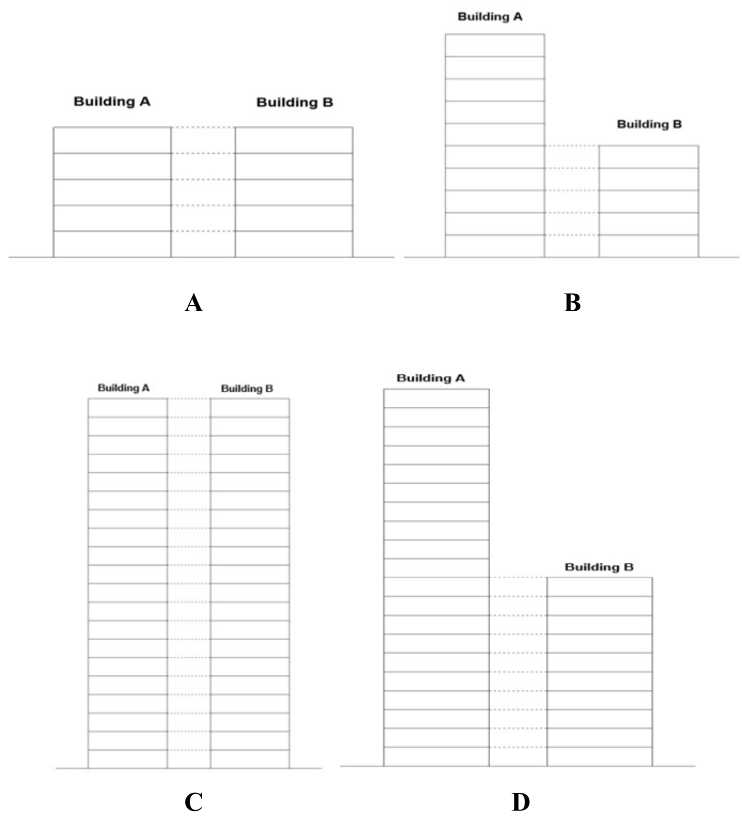

Figure 2. AView of the height of two buildings with reinforced concrete frame for examples 1a and 1bB2a and 2b C3a and 3b models andD4a and 4bmodels

4. Results

In order to minimize the cost of dampers, the response of two adjacent buildings by taking only three dampers (almost 50% of the total) with examining the obtained optimized properties damper by Xu et al. (1999) studied at the site of selected floors has been studied. For damperssites, the floors with maximum partial displacement have been selected. The following charts show the change of displacement in the all floors for different items. It should be noted that the maximum amount of displacement in the original duration of 60 seconds forfollowing selected charts has been intended. To show overall effect of fluid viscous damper in the adjacent buildings, the standard deviation of displacement on each floor of each building with and without damper using selected earthquake areshown.

For model 1a, Figure 3 shows the absolute displacement changes, that is, when the (i) is not connected, the (ii) is binding (connection) on all floors, the (iii) is the connection in floors of 3, 4 and 5 and the (iv) is connection in floors of 1, 3 and 5. It can be seen thatdampers are more effective when are placed in floors of 3, 4 and 5. When the dampers have been installed in these floors, displacement in all floors is reduced almost as much as when they have been connected in all floors. Thus, floors of 1, 3 and 5 are considered as the optimal sites to put damper. Damper installation in the proper site greatly reduces the costs of the dampers.

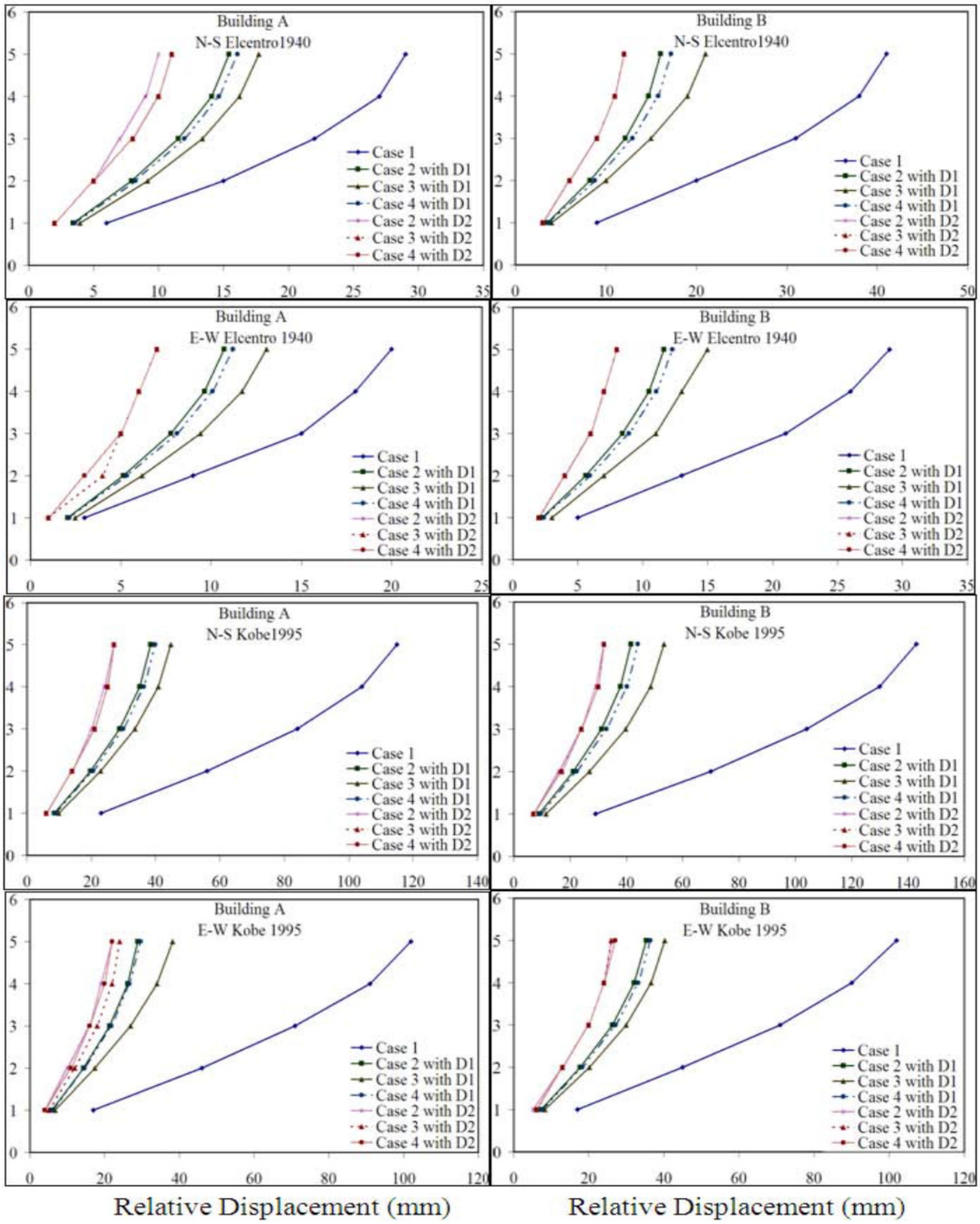

Figure 3. Displacement changes along the floors for example 1a

For model 1b, using damper in adjacent buildings with the same height is more efficient whenthe case of 4 with damper 2 is used for two adjacent buildings (Figure 4).

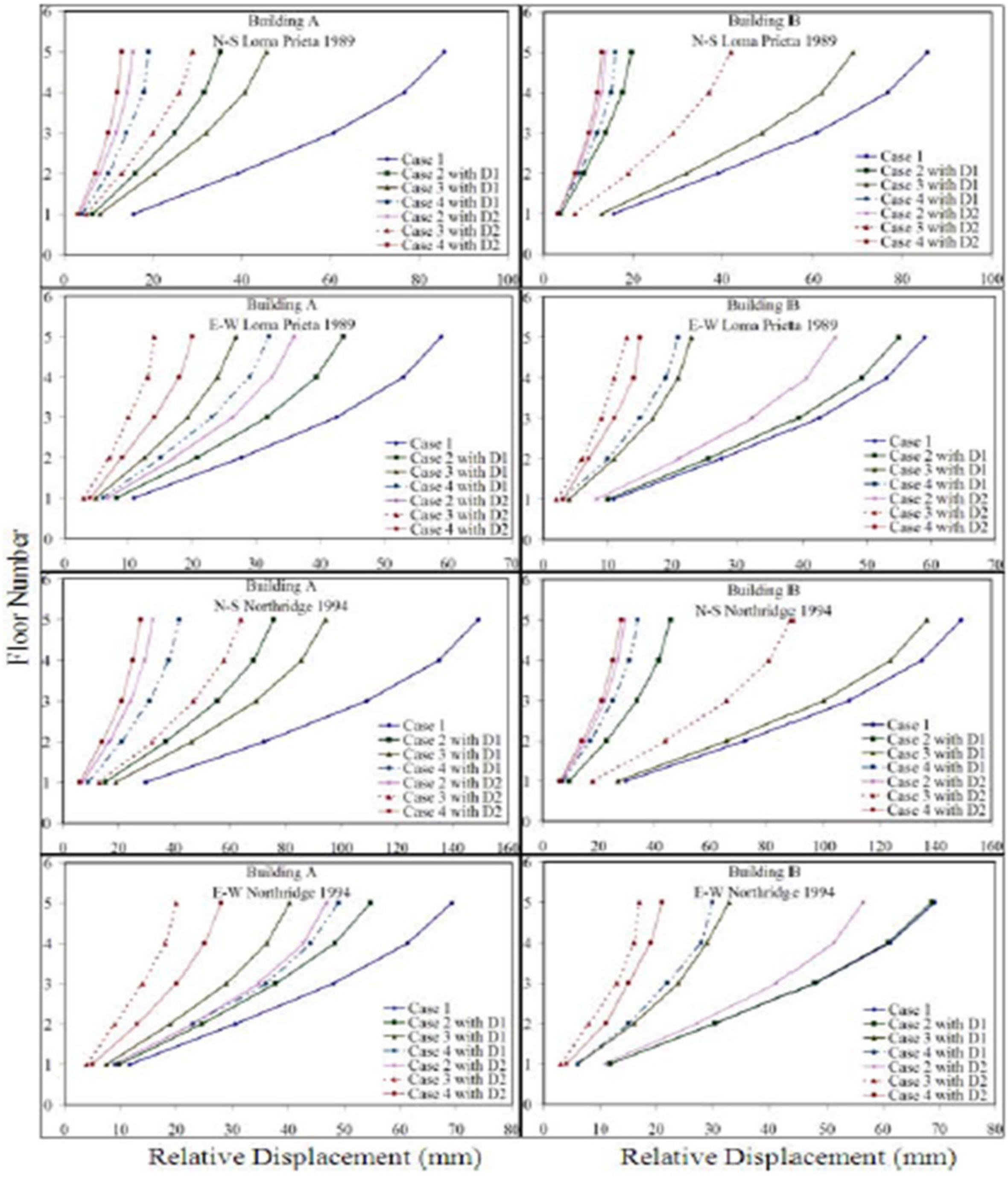

Figure 4. Displacement changes along the floors for example 1b in two directions

In the model 2a, the absolute displacement changes are shown in Figure 5. The results showed that for buildings B, damper is more effective when placed in floors of 3, 4 and 5. However, for buildings A, using dampers when they are placed in mentioned floors are not effective.

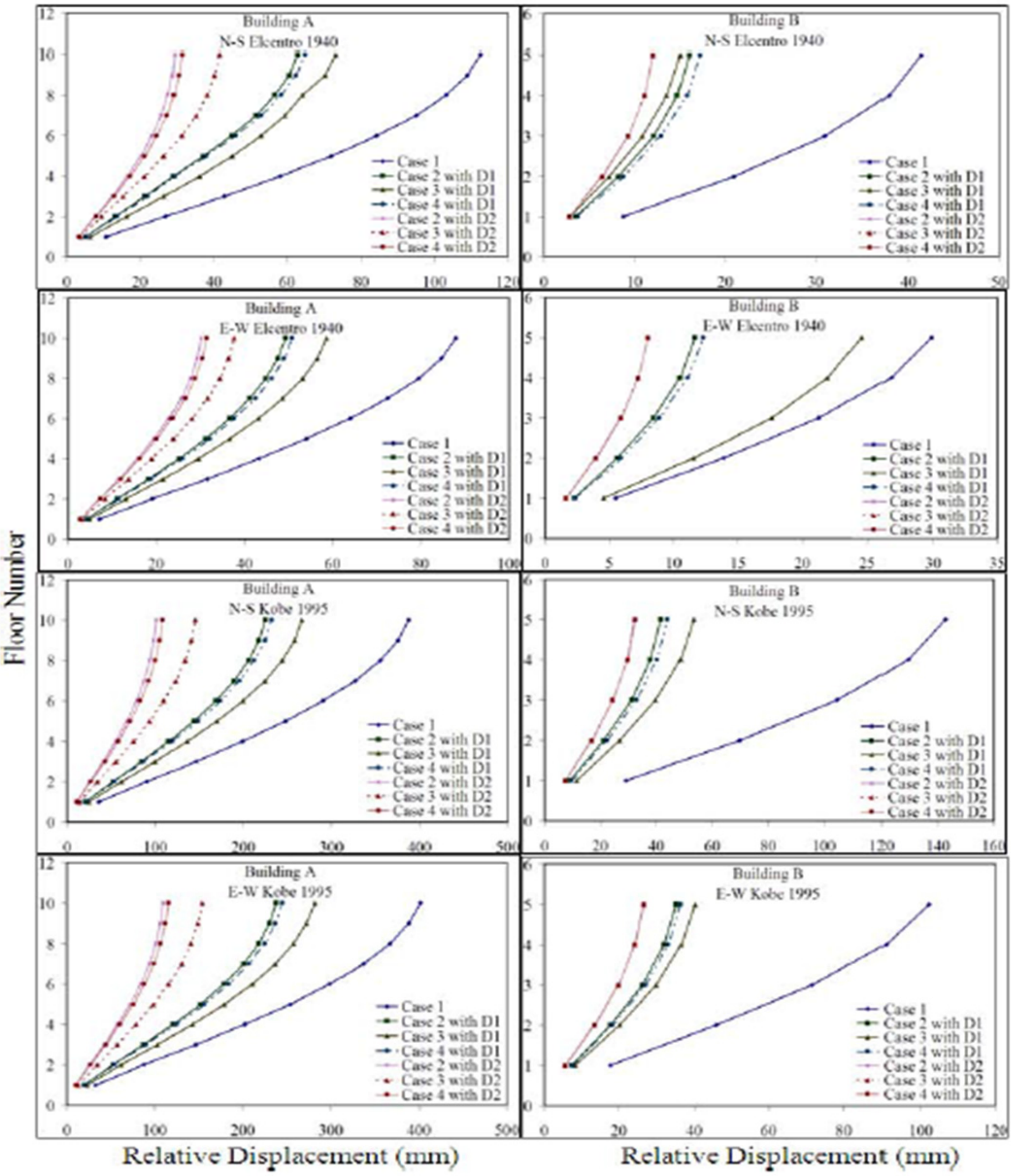

Figure 5. Displacement changes along the floors for example 2ain two directions

For example 3a, the absolute displacement changes are shown in Figure 6-5, in this sample damper in four insertions: (i) not connected, the (ii) connected on all floors, the (iii) connected in floors of 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 and (iv) connected in floors of 1, 3, 5, 7, 9, 11, 13, 15, 17 and 19, respectively. The results showed that the damper installationfor adjacent buildings with different heights in the case of they are placed on selected classes (iv) especially inlow-height buildings are more effective.

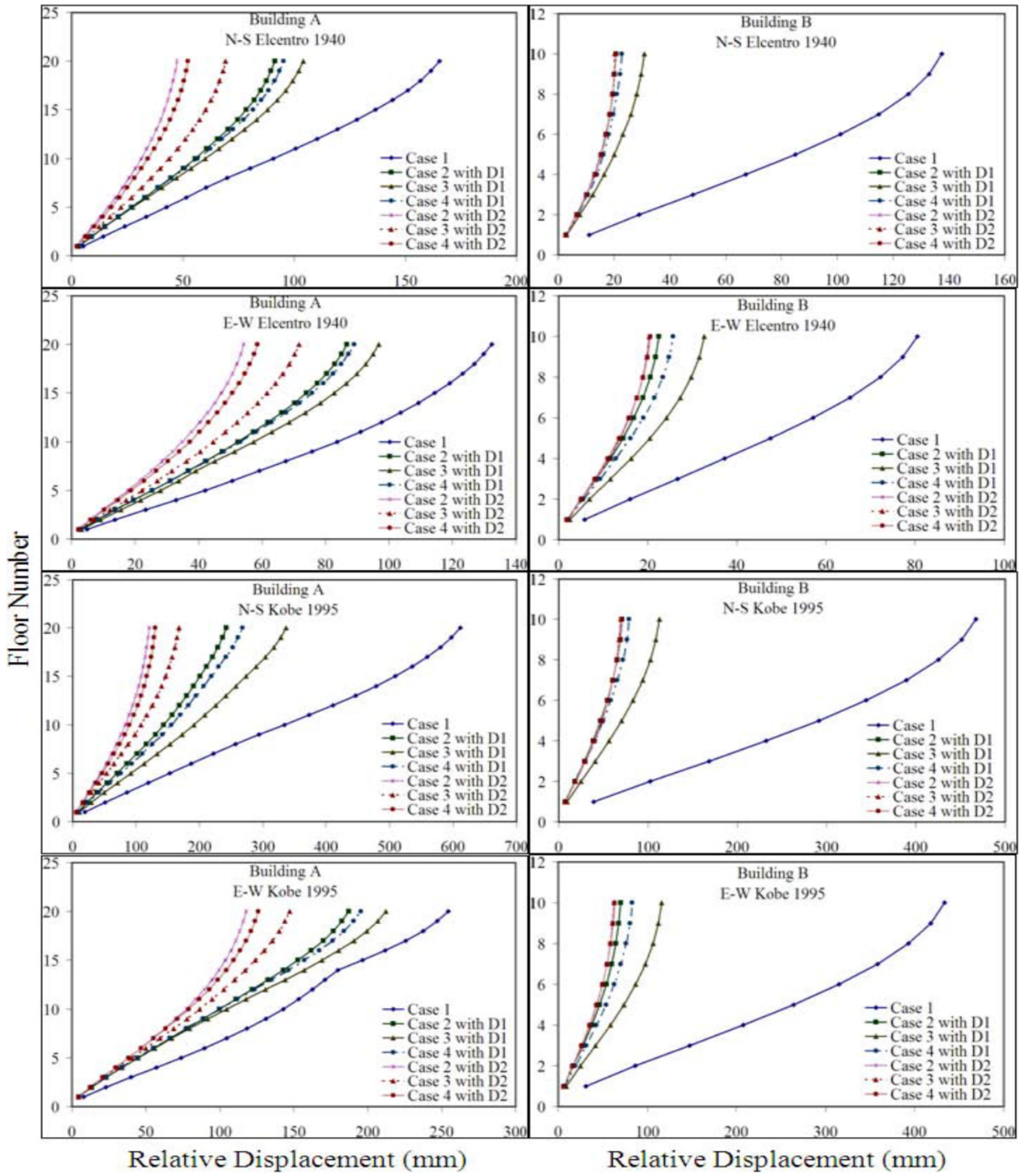

Figure 6. Displacement changes along the floors for example 3a

However, the results showed that for earthquakes in East-West direction, the use of damper can't be very effective. The results also showed that for buildings with similar dynamic features but different heights, fluid viscous damper can'thasanimportantrolein reducing effects of some large earthquakes (Figure 7).

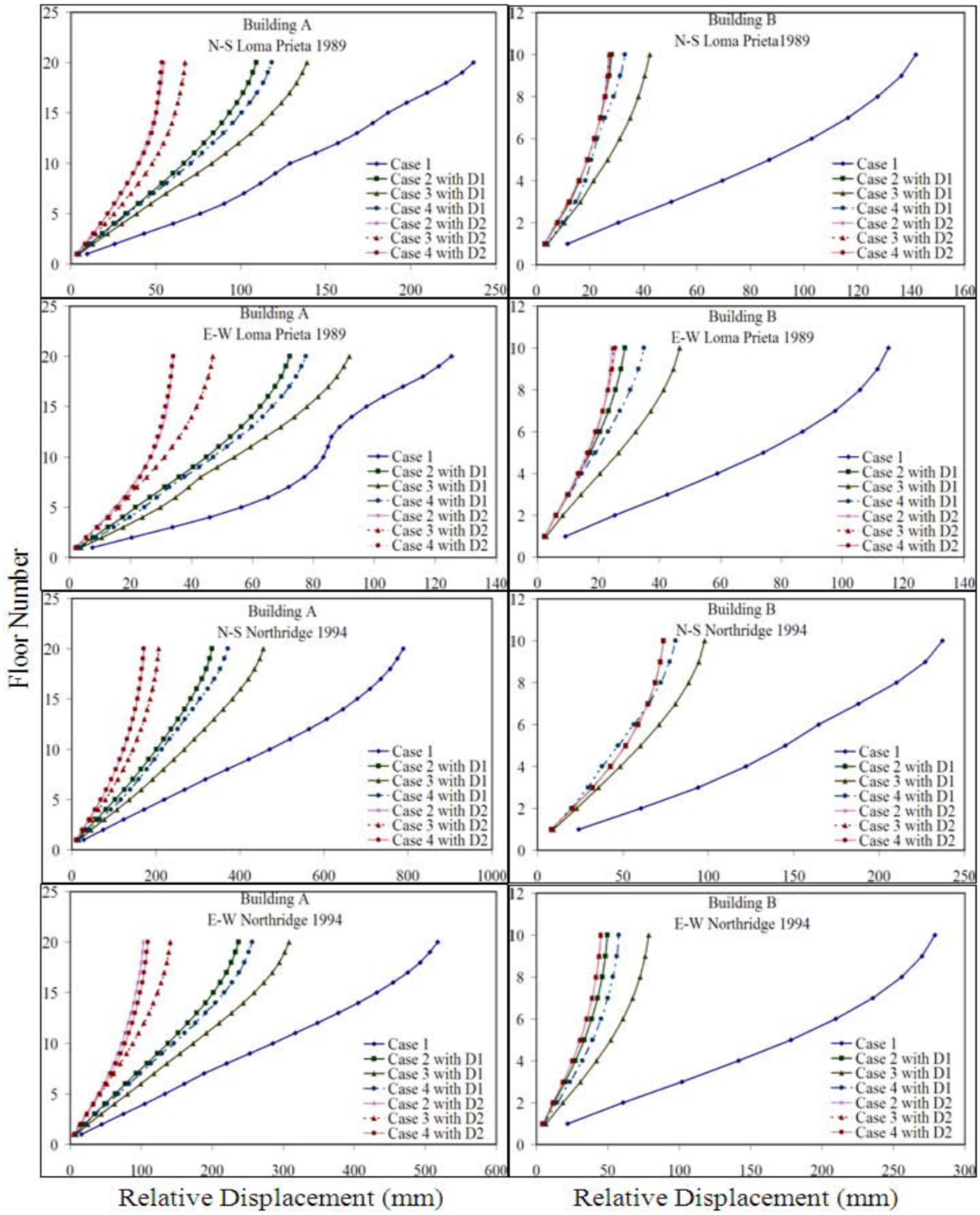

Figure 7. Displacement changes along the floors for example 3b in two directions

Applyingthe damper on selected floors for example 2 is more effective than Example 3. For example 4a, the absolute displacement changes compared to number of floors is shown in Figure 8. The results show that in most cases dampers in adjacent buildings withdifferent shear stiffness of the damperswhen are placed on all floors are more effective.

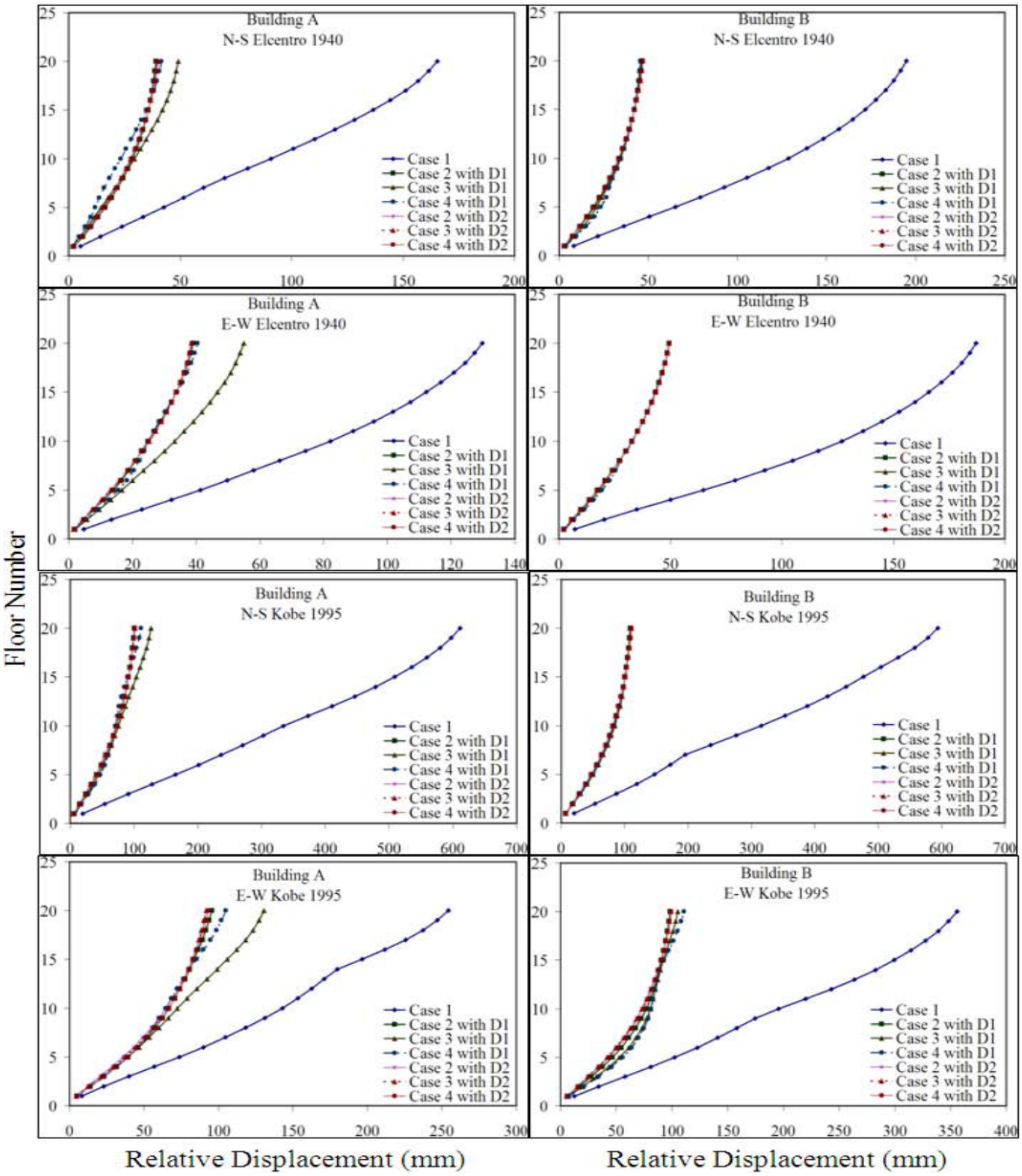

Figure 8. Displacement changes along the floors for example 4a in two directions

Moreover, the displacement domain for connected buildings by dampers located on all floors is reduced. Figure 9 shows displacement changes along the floors, for example 4b in two directions.Examples 4a and 4b show thatapplyingdampers with insertions of 2, 3 and 4 in buildings with different shear stiffness in reducing the effects of earthquakes is more effective than buildings with the same shear stiffness.

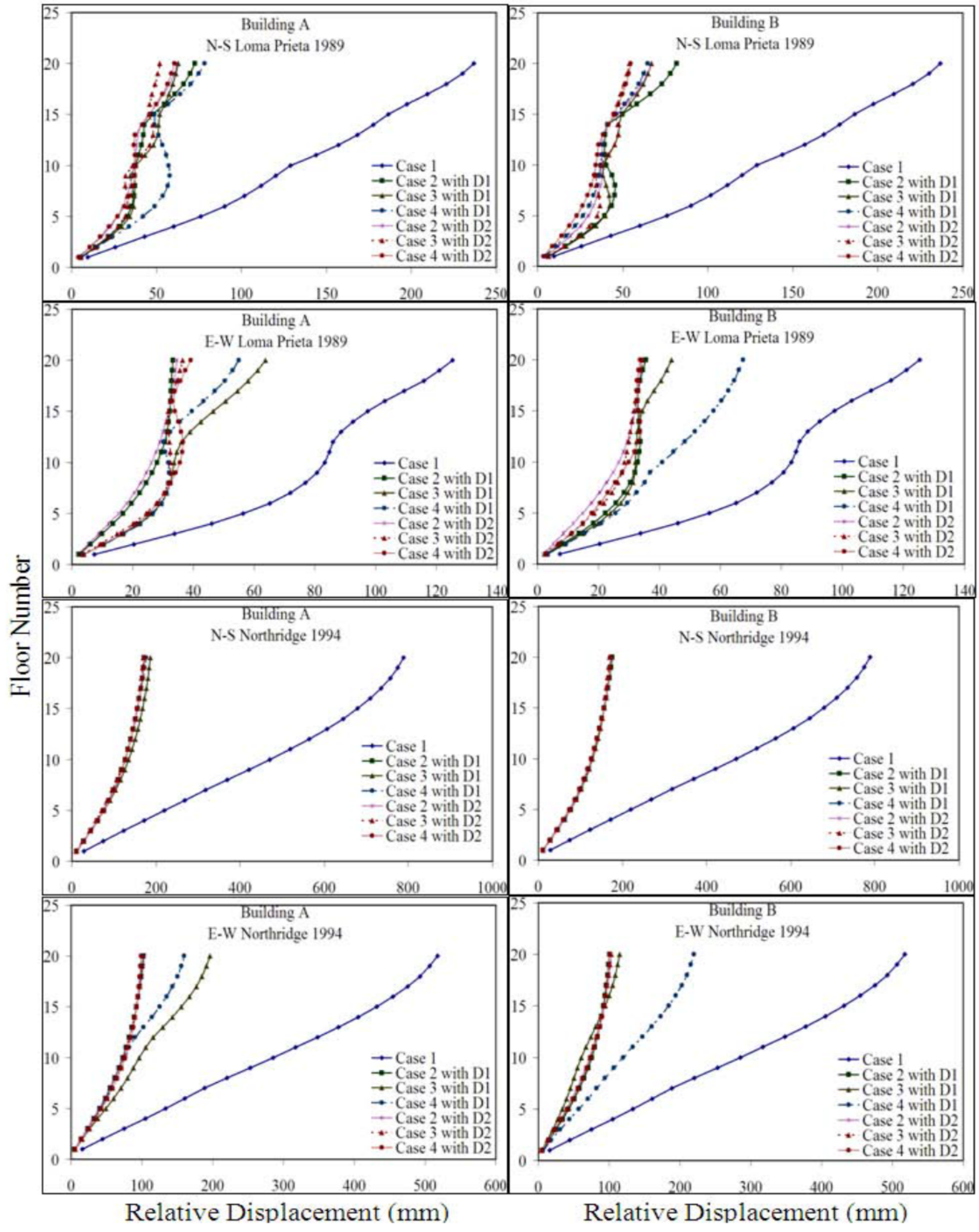

Figure 9. Displacement changes along the floors for example 4b in two directions

5. Conclusion

Absolute displacement changes to find the optimal location (site) to put the dampers for the mentioned items were shown. All calculated samples in each case indicate that the insertion of dampers in the right place (site) can be significantly effective in reducing seismic response of the connected systems. This greatly reduces the costs of dampers.

In this study, to reduce the costs of fluid viscous damper, adjacent buildings response by considering several specific dampers (for example, about 50% of the total) with specified optimized parameters on the selected floors were studied. For shorter building less dampers with appropriate insertion can be more effective than using the dampers on all floors. However, for high-rise buildings, the opposite of above situation can be occurred in large earthquakes. The results showed that the change of damping parameters in terms of attenuation coefficients is important to reduce the displacement of the top floor of adjacent buildings.

The results also showed that the damper 2, which has a higher damping coefficient than the damper 1, is more advantageous. The results showed that the fluid viscous dampersare effective in reducing the seismic response of adjacent buildings. This study shows that it is not necessary two adjacent buildings connected by a damper on all floors, but the less damper in appropriate selected locations (sites) can help to reduce the earthquake response. Although less damper can be effective in reducing the response, but this decrease would be much more than others when the dampers are located on all floors. This study can be extended in the future for the mode in which two adjacent high-rise building with different damping characteristics by connecting new and different damper.

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