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Study on Methods to Control Interstory Deflections

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Received: 13 January 2020; Accepted: 17 February 2020; Published: 18 February 2020

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Abstract: One of the possibilities to prevent building pounding between two adjacent structures is to consider appropriate in-between separation distance. Another approach might be focused on controlling the relative displacements during seismic excitations. Although the majority of building codes around the world recommend the use of some equations of various distances between structures to avoid pounding; a lot of reports after earthquakes have obviously shown that safety situation or economic consideration is not always provided due to the collisions between buildings and high cost of land; respectively. The aim of the present paper is to focus the analysis on the properties of structures and conduct an in-depth analysis of available methods to control interstory deflections so as to prevent pounding. For this purpose, a numerical lumped mass model of the five-story building has been considered and its response under different earthquake records has been investigated. Firstly, the influence of the change in structural properties (story stiffness; mass and damping) has been examined. Then the application of tuned mass damper, base isolation and base isolation with rubber bumpers has been considered. The results of comparative analyses clearly indicate that using base isolation, with the addition of bumpers, can be selected as the best method to control building deflections and decrease absolute lateral displacement between two buildings so as to prevent their pounding during earthquakes

Keywords: earthquakes; structural pounding; buildings; parametric study; interstory deflections

1. Introduction

The philosophy of structural pounding during earthquakes is demonstrated by collisions between buildings, or bridge segments, when they are located close to each other without appropriate distance (see [1–3] for example). The large relative displacement of adjacent structures causes collisions and may provide serious damage [4,5]. In order to avoid any impact incidences between buildings during seismic excitations, two approaches are usually considered depending significantly on the distance between the structures and properties of buildings. One of them is to consider sufficient in-between separation so as to prevent pounding [6]. This solution, however, may not be accepted in metropolitan cities due to the high cost of land. Therefore, some methods to control structural deformations can be considered instead. For example, Anagnostopoulos and Karamaneas [7] as well as Barros and Khatami [8] analyzed numerically the effectiveness of concrete shear wall to increase the stiffness of buildings in order to minimize the required gap size preventing pounding between adjacent structures with fixed supports. Another philosophy to control structural deformations is to use the base isolation system [9]. It allows us to tune the structures so as to have the in-phase vibrations while some amount of energy can be dissipated at the same time (see [10–12] for example). Moreover, Jankowski and Mahmoud [13], Zhang and Xu [14] and Matsagar and Jangid [15] investigated the effectiveness of links between adjacent structures by using springs and dashpots to reduce relative displacements of structures. Connections between adjacent buildings by additional stiff beams to absorb energy were also evaluated by Westermo [16]. The author used a special link element, which is able to dissipate energy and decrease impact force during collisions (see also [17,18]). Kasai et al. [19] eliminated pounding effects by applying viscoelastic dampers at the level of contact between buildings. The effects of rubber bumpers were also considered by Polycarpou and Komodromos [20], Polycarpou et al. [21] and Raheem [22]. Finally, Dogruel [23], Braz and Barros [24] as well as Lopez-Garcia and Soong [25,26] focused their analyses on the effectiveness of passive dampers by using, among other methods, the genetic algorithms for optimal seismic design of nonlinear structures.

Moreover, Favvata in [27] analyzed interstory pounding based on the seismic behavior of multi-story reinforced concrete structures designed to contemporary seismic codes. In [28], Favvata et al. investigated the seismic interaction between structures with different story heights taking into account the local response of the exterior beam-column joints. The results of this study show that the possible local inelastic reaction of external joints may be, in some cases, beneficial to the behavior of a critical column that is impacted. In paper [29], an extensive study has been conducted focused on the seismic performance of reinforced concrete frame structures with irregularities leading to the soft first floor. The authors concluded that the global capacity of the structures is decreased due to the considered first floor irregularities comparing to regular structures. Karayannis et al. [30] studied the effects of the exterior joints capacity on the failure mechanisms of reinforced concrete structures with infills. The results of the investigation show that the possible local damage of the exterior joints may lead to erroneous consequences and may sometimes become critical. Moreover, the influence of infills on the structural deflections was found to be substantial leading to considerable reduction in the seismic response of structures.

The aim of the current study is to consider the best mitigation of displacements and control deflections of structures in order to reduce building pounding hazard under seismic excitations. In fact, the behavior of the model with different configurations is investigated to find the best solution for decreasing lateral displacement and, subsequently, to avoid collisions between adjacent buildings during earthquakes. For this challenge, a numerical model of the five-story building is considered and six different earthquake records are selected to examine the effectiveness of various methods. Firstly, the influence of the change in structural properties (story stiffness, mass and damping) is examined. Then, the application of Tuned Mass Damper (TMD), base isolation and base isolation with rubber bumpers are considered.

2. Materials and Methods

Investigation of the best mitigation of the relative displacement of structures was carried out by using the lumped mass multi degree-of-freedom model of the five-story building under different configurations (fixed supports, fixed supports with TMD, isolated supports and isolated supports with rubber bumpers), as shown in Figure 1. Models were considered as the simplified lumped-mass dynamical systems and analyzed within the elastic range using a specialized computer program, written by the authors, that is able to investigate and evaluate the dynamic behavior of different models under various earthquake excitations. The numerical model with fixed supports was specifically considered as an original one and the results of the top story displacement of the building were selected to be compared with other responses for different earthquake records. The model was assumed to be characterized by the story stiffness equal to 1.06×10^6 N/m, story mass of 2560 kg and damping ratio of 5%. The height of each story was assumed to be 3.00 m, which makes a total height of the structure equal to 15.00 m. The plan of the structure was considered to be square with 5.00 m for each direction and having a mass of 100 kg/m^2. The natural period of buildings was mathematically considered in the numerical models by stiffness and mass matrix and calculated as equal to 0.58 s for the model with fixed supports and 1.22 s for the model with isolated supports. The numerical analysis was conducted for six earthquake records, i.e., El Centro (1940), Parkfield (1966), San Fernando (1971), Landers (1992), Kobe (1995) and Kocaeli (1999), see Table 1.

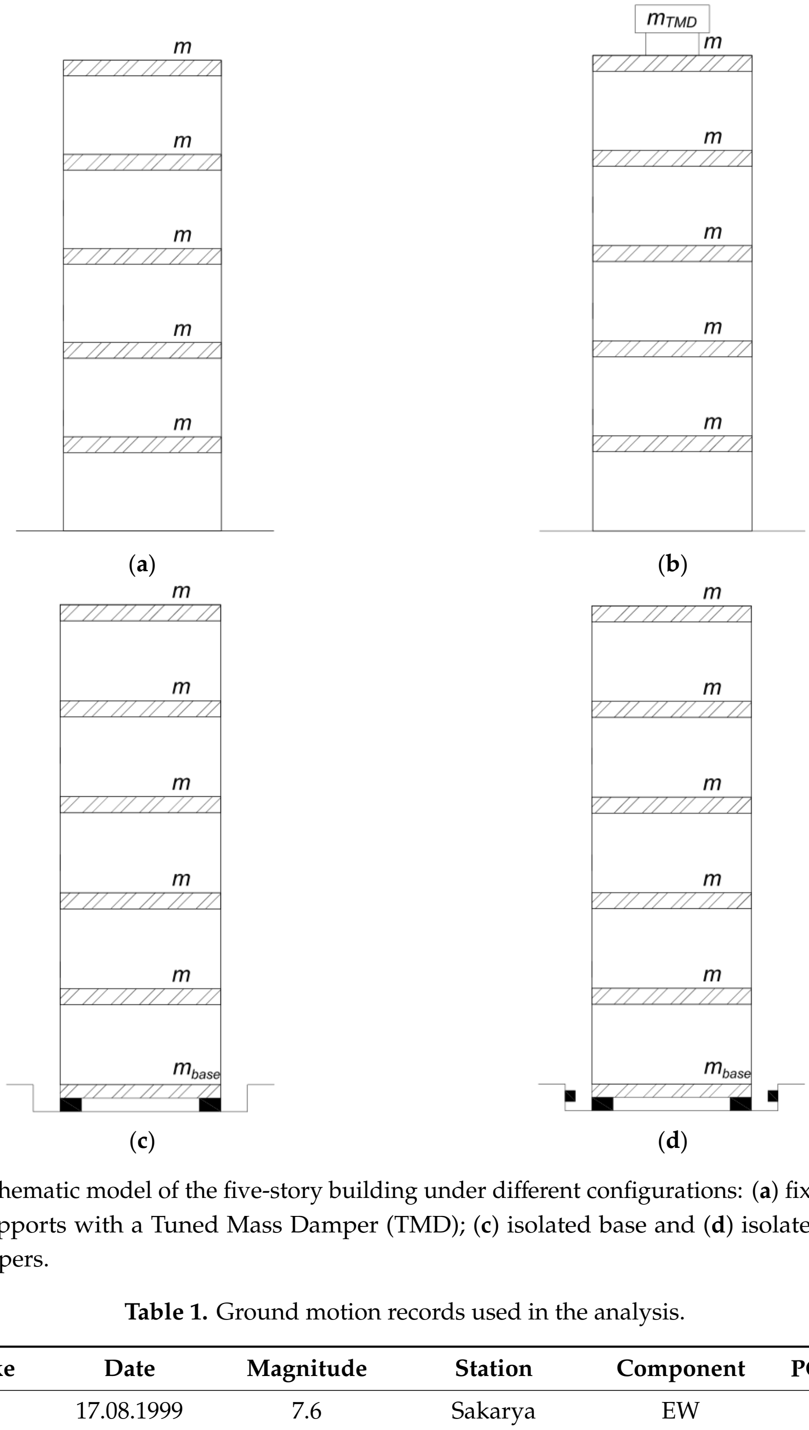


Figure 1. Schematic model of the five-story building under different configurations: (**a**) fixed supports; (**b**) fixed supports with a Tuned Mass Damper (TMD); (**c**) isolated base and (**d**) isolated base with rubber bumpers.

Table 1. Ground motion records used in the analysis.

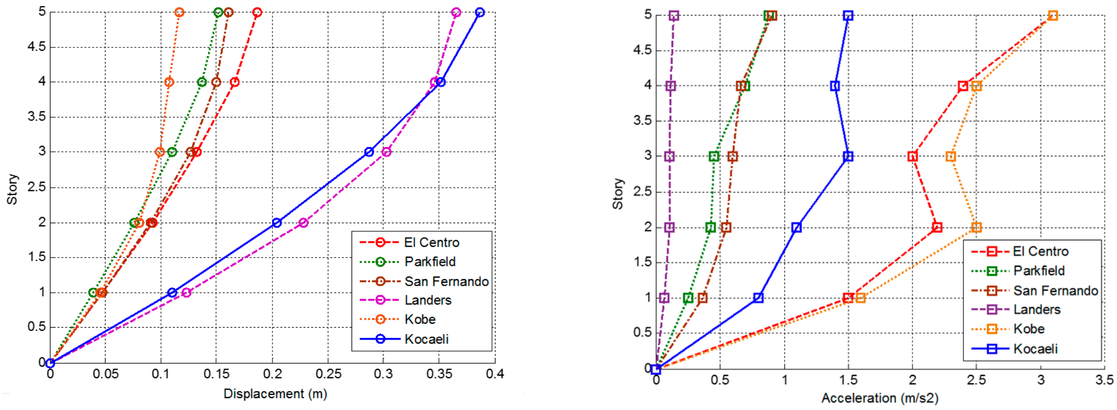
Earthquake	Date	Magnitude	Station	Component	PGA (cm/s^2)
Kocaeli	17.08.1999	7.6	Sakarya	EW	369.28
Kobe	17.01.1995	7.2	JMA	NS	817.82
Parkfield	28.06.1966	6.2	Jennings (CGS)	NS	462.00
El Centro	18.05.1940	6.9	El Centro	NS	307.00
San Fernando	09.02.1971	6.6	Pacoima Dam	N16° W	1202.62
Landers	28.09.1992	7.3	Baker	SS	853.00

PGA—Peak Ground Acceleration.

3. Results and Discussion

3.1. Original Building

Firstly, the five-story numerical model of the original building (see Figure 1a) under six earthquake records was analyzed. The results of the analysis in the form of the peak lateral displacement and peak acceleration values for different stories of the building are shown in Figure 2. It can be seen from the figure that the peak lateral displacements were equal to 11.68 cm, 15.19 cm, 16.11 cm, 18.65 cm, 36.53 cm and 38.69 cm for the Kobe, Parkfield, San Fernando, El Centro, Landers and finally the Kocaeli earthquake, respectively. Moreover, the peak accelerations were equal to 14.15 cm/s^2, 81.9 cm/s^2, 91.0 cm/s^2, 150.0 cm/s^2, 309.0 cm/s^2 and 310.0 cm/s^2 for the Landers, Parkfield, San Fernando, Kocaeli, El Centro and finally the Kobe earthquake, respectively.

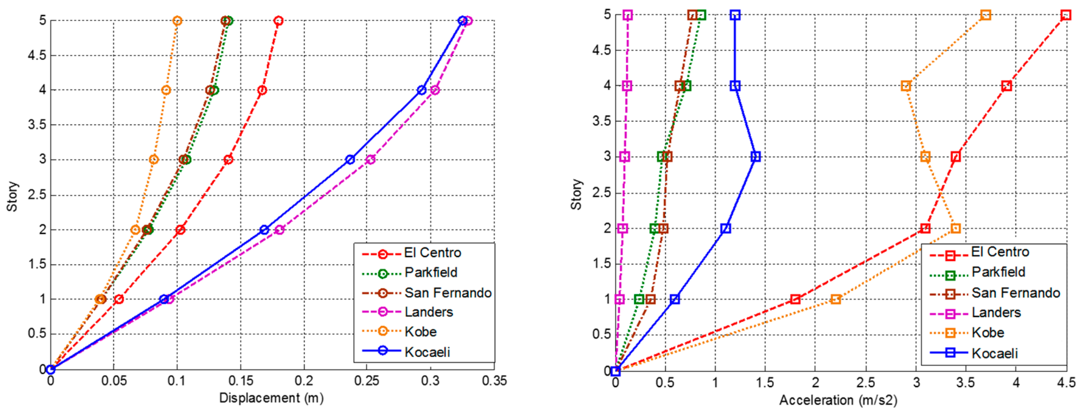


(**a**) (**b**)

Figure 2. The results of (**a**) peak displacement and (**b**) peak acceleration for different stories of the building.

3.1.1. Changing Story Mass

In order to investigate the influence of the story mass to control displacements for reducing pounding hazard, a percentage of original story mass with a value of 80% of the original mass was considered while stiffness and damping of the model were kept unchanged. The results are shown in Figure 3. It can be seen from the figure that the peak lateral displacement, equal to 32.93 cm, was observed for the Landers earthquake and it had a slight decrease (by about 10%) as compared with the original model.



(**a**) (**b**)

Figure 3. The results of (**a**) peak displacement and (**b**) peak acceleration for different stories of building after changing the story mass.

The results of the investigation focused on the influence of story mass pointed clearly out that by decreasing story mass, the lateral displacements were normally declined and the accelerations were increased. In particular, reducing the story mass of the structure by 20% was able to change the peak lateral displacement by about 10%, which could be enough to avoid collisions between adjacent buildings and substantially decrease pounding hazard during seismic excitations.

In the next stage of analysis, the story mass of the model was changed from 0 to 5000 kg (by 10 kg steps) and the peak displacements for the top story of the building were determined. The results of the analysis are presented in Figure 4. The figure shows an increasing trend for increasing the values of story mass. For example, the peak displacements were equal to 149.25 cm, 74.36 cm, 63.75 cm, 59.85 cm, 55.65 cm and 54.28 cm for the Landers, Kobe, Parkfield, Kocaeli, San Fernando and El Centro earthquake, respectively, when the story mass was equal to 5000 kg.

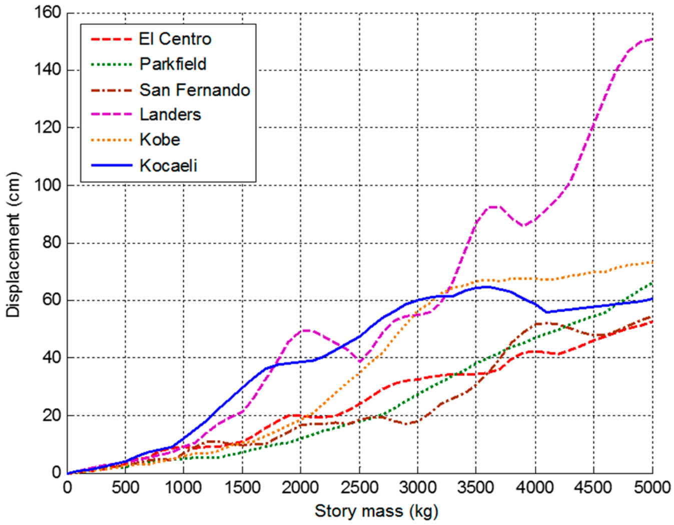
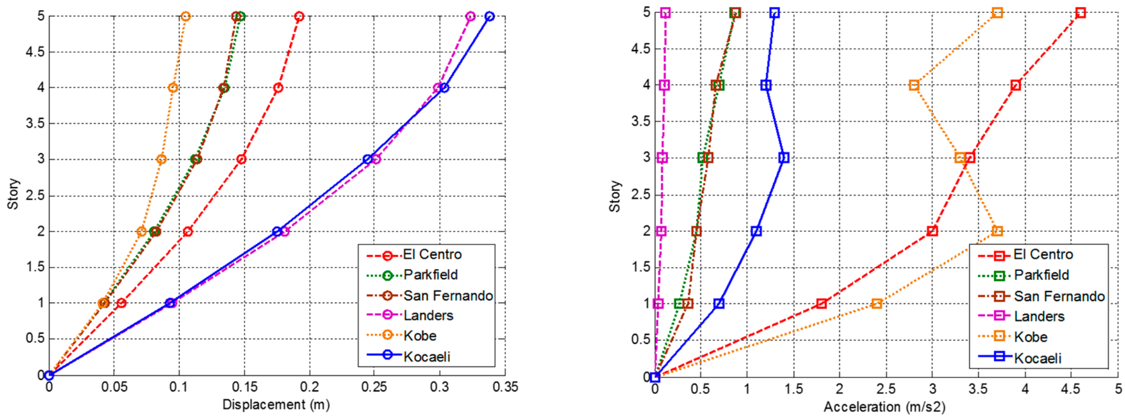


Figure 4. Peak displacement for the top story of building with respect to story mass.

3.1.2. Changing Story Stiffness

In this part, the story stiffness of building was changed so as to evaluate the relative displacement and story acceleration for controlling story deflections. For this purpose, the values of story mass and damping were kept constant while the story stiffness of the model was increased by 20%. The results are shown in Figure 5. It can be seen from the figure that the increase in story stiffness caused a decrease in the lateral displacement and the increase in the story acceleration. The peak lateral displacement was equal to 33.84 cm for the Kocaeli earthquake, it was slightly reduced to 32.34 cm for the Landers earthquake and it was sharply declined to 19.21 cm, 14.74 cm, 14.42 cm and finally 10.51 cm for the El Centro, Parkfield, San Fernando and Kobe earthquake, respectively. The results of the analysis indicate that there was about a 13% decrease in terms of peak lateral displacement when the story stiffness increased by 20%, as compared with the original model. The decreasing trend of peak displacement concerned the range of story stiffness from 0 to 3×10^6 N/m, as can be seen from Figure 6.



(**a**) (**b**)

Figure 5. The results of (**a**) peak displacement and (**b**) peak acceleration for different stories of building after changing the story stiffness.

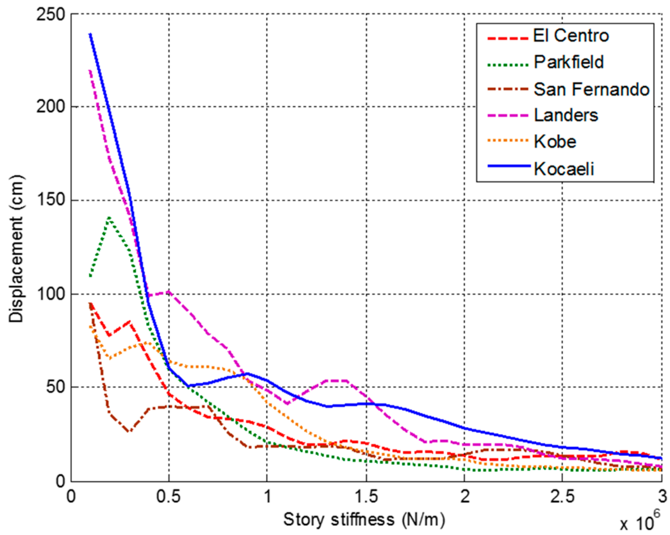
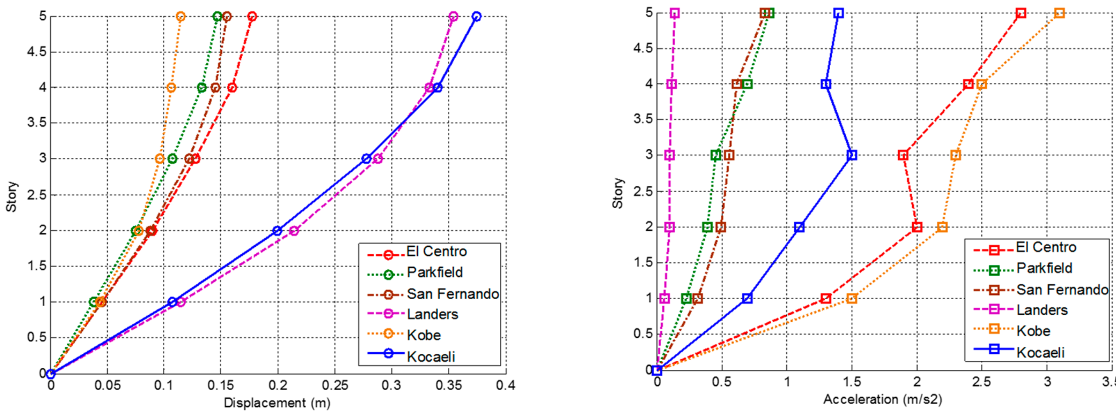


Figure 6. Peak displacement of the top story of building with respect to story stiffness.

3.1.3. Changing Story Damping

In the third part of the investigation, the story damping was significantly increased while the story mass and stiffness were kept unchanged. The increase was assumed to be equal to 40%, which was believed to be able to reduce structural vibrations. Figure 7 presents the peak lateral displacements and accelerations for different stories of building under different earthquakes. It can be seen from the figure that the peak displacements for the top story were equal to 11.46 cm, 14.66 cm, 15.57 cm, 17.76 cm, 35.44 cm and 37.45 cm for Kobe, Parkfield, San Fernando, El Centro, Landers and finally Kocaeli earthquake, respectively. As it can be calculated, the increase in damping by 40% caused a decrease in the peak lateral displacement by about 4% in comparison with the original model.



(a) (b)

Figure 7. The results of (**a**) peak displacement and (**b**) peak acceleration for different stories of building after changing the story damping.

As it is obviously seen, the maximum acceleration was related to the case when the minimum lateral displacement took place. For instance, the Kobe earthquake induced the peak story acceleration of 307.0 cm/s^2 and the minimum lateral displacement of 11.46 cm among all earthquake records, while the corresponding values for the original model were equal to 310.0 cm/s^2 and 11.68 cm, respectively.

There was an irregular decreasing trend for peak displacements obtained for different earthquake records when the story damping was increased. The trend concerned the range of story damping from 0 to 5000 N.s/m, as can be seen from Figure 8.

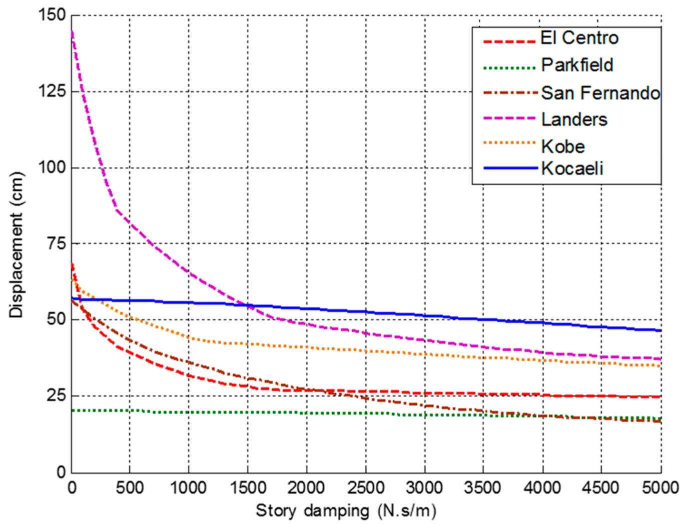
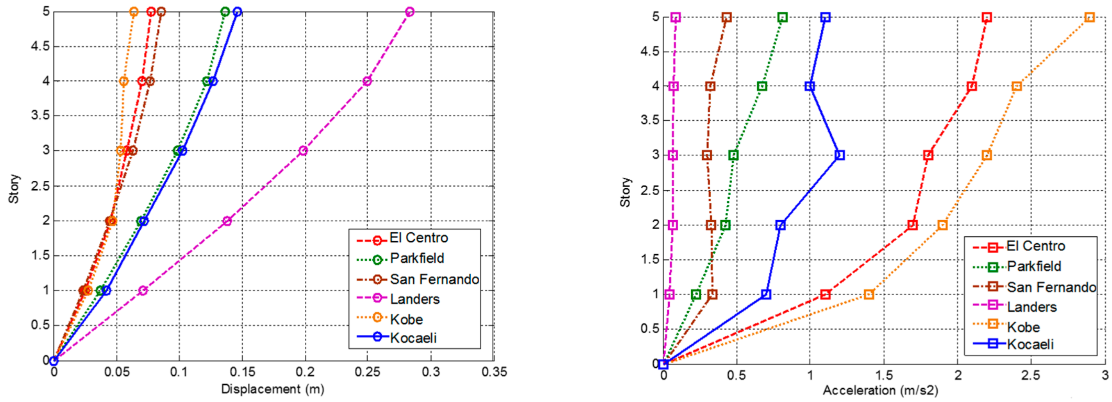


Figure 8. Peak displacement for the top story of building with respect to story damping.

3.2. Building with Additional Devices

3.2.1. Using TMD

TMD is a device that is generally installed at the top of the building in order to reduce structural vibrations under earthquake and wind loading. In fact, TMD decreases vibrations of a system and controls the irregular deformations by decreasing lateral displacements. In order to investigate the effectiveness of TMD in controlling the lateral displacement of the analyzed building, a damper with a mass of 4000 kg and stiffness of 0.28 M.N/m was assumed to be installed at the top of the structure (see Figure 1b). The model was studied under all earthquake records and the peak displacement and acceleration values for different stories of the building were calculated, as shown in Figure 9. It can be seen from the figure that the peak displacement was equal to 28.37 cm, 14.63 cm, 13.69 cm, 8.62 cm, 7.7 cm and 6.4 cm for the Landers, Kocaeli, Parkfield, San Fernando, El Centro and Kobe earthquake, respectively. These results indicate that the lateral displacements were significantly reduced after the installation of TMD. For instance, the peak displacement of the original model under the Landers earthquake was equal to 38.69 cm and the value decreased up to 28.37 cm after using TMD (see Figure 9), which gave the reduction by about 27%.



(**a**) (**b**)

Figure 9. The results of (**a**) peak displacement and (**b**) peak acceleration for different stories of building with TMD.

3.2.2. Using the Base Isolation System

In this stage of the study, the behavior of the base isolation system (see Figure 1c) was numerically investigated and the results of analyses were evaluated so as to verify the effectiveness of the system. Different techniques can be used for the isolation system. These include the application of rubber bearings, friction bearings, ball bearings, polymer bearings, spring systems and other means. In the present study, four rubber bearings were assumed to be installed at the corners of the foundation of the analyzed building. The mass of the isolated base was equal to 2560 kg, while the viscous damping, initial stiffness and the post-yield stiffness of the base isolation system were equal to 5243 N.s/m, 0.37×10^6 M.N/m and 0.045×10^6 M.N/m, respectively. The results of the analyses in the form of peak absolute and relative displacement values for different stories of building with base isolation system are shown in Figure 10. It can be seen comparing Figure 10a with Figure 2a that the absolute displacements for the base-isolated structure were much larger than for the fixed-base structure. For example, the peak absolute displacement for the top story of the structure with base isolation system was equal to 47.97 cm under the Landers earthquake and it was equal to 36.53 cm for the building with fixed supports under the same ground motion, what gives 11.44 cm difference between both values. However, it can also be clearly seen from Figure 10b that the application of base isolation led to a considerable reduction in the relative displacements in relation to the isolated base. The peak relative displacement was equal to 5.86 cm, 8.72 cm, 10.39 cm, 14.52 cm, 18.59 cm and 22.64 cm for the Kobe, El Centro, San Fernando, Parkfield, Kocaeli and Landers earthquake, respectively (see Figure 10b). That gives the reduction by as much as 50.1%, 53.2%, 35.5%, 4.4%, 51.9% and 38.0% for the Kobe, El Centro, San Fernando, Parkfield, Kocaeli and Landers earthquake, respectively, as compared with the case of building with fixed supports (see Figure 2a).

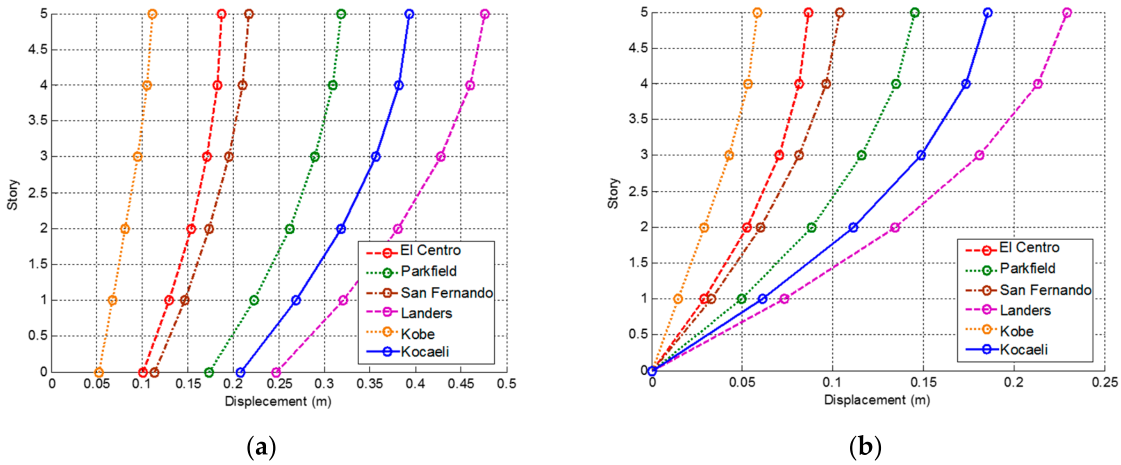


Figure 10. The results of (**a**) peak absolute displacement and (**b**) peak relative displacement for different stories of building with base isolation system.

3.2.3. Comparison of Different Approaches

In order to further investigate the best method for controlling the displacement so as to reduce the pounding hazard during seismic excitations, the peak lateral relative displacements (with relation to the isolated base) for the top story of building were compared with each other. An original five-story model of the structure was considered as a reference one and different cases, such as changing story mass, stiffness and damping, using TMD and base isolation system, were compared with it. The results of the comparative analysis obtained for different earthquakes are shown in Table 2 and Figure 11.

Table 2. Peak relative displacement for the top story of building for different cases (cm).

Earthquake	Original Model	Changing Story Mass	Changing Story Stiffness	Changing Story Damping	Using TMD	Using the Base Isolation System
El Centro	18.65	18.02	17.21	17.76	7.7	8.72
Parkfield	15.19	13.83	14.42	14.66	13.69	14.52
San Fernando	16.11	14.05	14.74	15.57	8.62	10.39
Landers	36.53	32.56	32.34	35.44	28.37	18.64
Kobe	11.68	10.01	10.51	11.46	6.4	5.86
Kocaeli	38.69	32.93	33.84	37.45	14.63	18.59

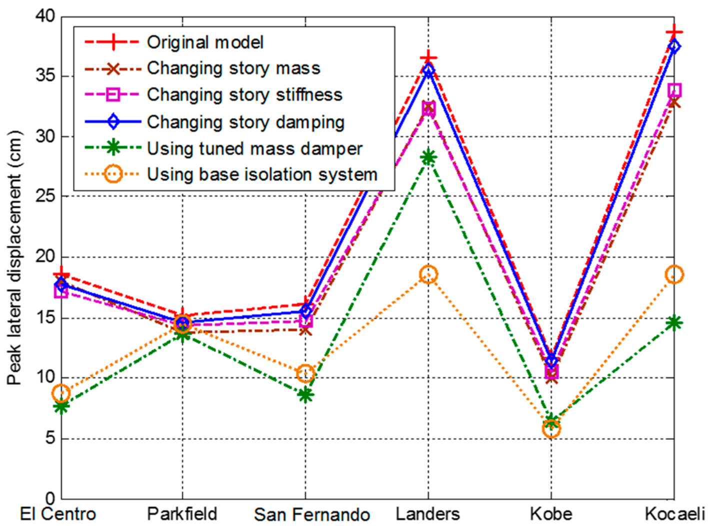


Figure 11. Peak relative displacement for the top story of building for different cases.

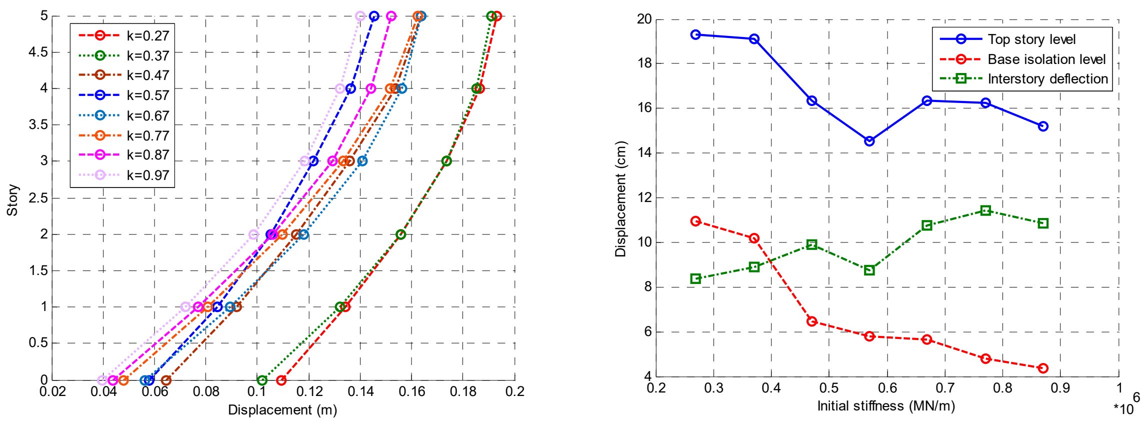
It can be seen from Table 2 and Figure 11 that the Kobe earthquake induced the smallest peak lateral relative displacements among all earthquake records considered in the analysis. On the other hand, the largest peak lateral relative displacements occurred under the Kocaeli earthquake for all situations, except for the one when the TMD was used. The average reduction in the peak relative displacement for all seismic excitations was equal to 12% (changing story mass), 11% (changing story stiffness), 4% (changing story damping), 42% (using TMD) and finally, 44% (using base isolation system), as compared with the original model.

3.3. Base-isolated Building

The results of previous analyses clearly show that the application of the base isolation system was the most effective method in reducing the relative displacements under different earthquakes. Therefore, further analysis was conducted focused on testing the sensitivity of parameters of the base isolation system and their influence on the structural response. Moreover, the application of rubber bumpers was also considered so as to reduce also the absolute displacements of building exposed to earthquake excitations.

3.3.1. Changing Initial Stiffness of Base Isolation

Firstly, in order to investigate the influence of the initial stiffness, the parameter was changed from 0.27×10^6 to 0.97×10^6 M.N/m, while keeping the same values of damping and mass of the base. The results of the analysis in the form of the peak lateral absolute displacements for different stories of the building and various initial stiffness of base isolation under the El Centro earthquake are shown in Figure 12a. Moreover, the peak lateral absolute displacements at the top story level and the base level as well as the interstory deflections are additionally presented in Figure 12b. It can be seen from Figure 12 that increasing the initial stiffness of the base isolation caused irregular responses of the structure. For instance, the top story absolute displacement was equal to 19.32 cm when the initial stiffness was set at the level of 0.27×10^6 M.N/m, then it had a sharp decrease up to 14.55 cm when the initial stiffness was considered to be 0.57×10^6 M.N/m, and finally, the increase in the displacement was observed (16.24 cm) when the initial stiffness was equal to 0.77×10^6 M.N/m.

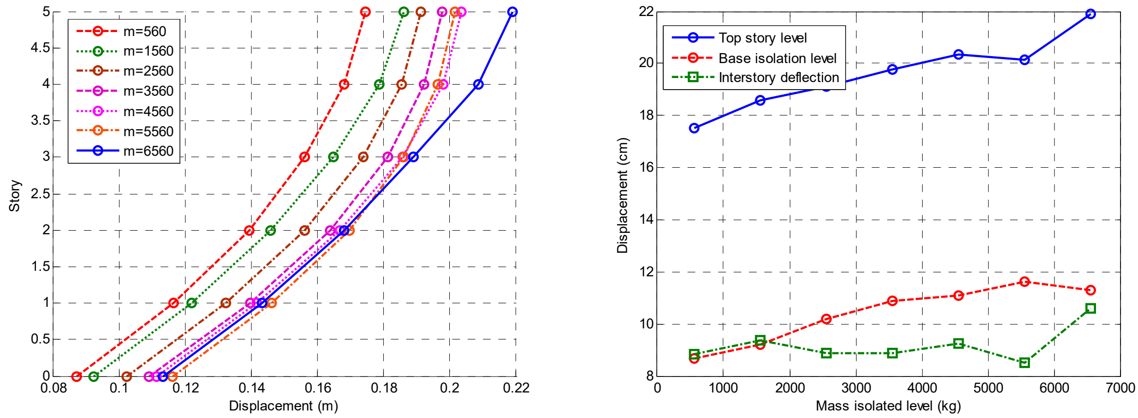


(**a**) (**b**)

Figure 12. The results of (**a**) peak displacement for different initial stiffness of isolated support (**b**) peak displacement at the base isolation level and top story level for different initial stiffness of isolated support under the El Centro earthquake.

3.3.2. Changing the Mass of the Isolated Base

The next stage of the analysis was focused on investigating the influence of the mass of the isolated base. The parameter was changed from 560 to 6560 kg, while keeping the same values of damping and initial stiffness. The peak lateral absolute displacements for different stories of the building and various mass values of the isolated base under the El Centro earthquake are shown in Figure 13a. Additionally, the peak lateral absolute displacements at the top story level and the base level as well as the interstory deflections are also presented in Figure 13b. It can be seen from Figure 13 that increasing the mass of the base led to an increase in the displacements. For instance, the base displacements were equal to 9.22 cm and 11.1 cm for mass values of 1560 kg and 4560 kg, while the top story absolute displacements increased from 18.59 to 20.35 cm at the same time. The results of analyses clearly indicate that increasing the mass of the isolated base by about 66% led to an increase in displacements by about 81%.

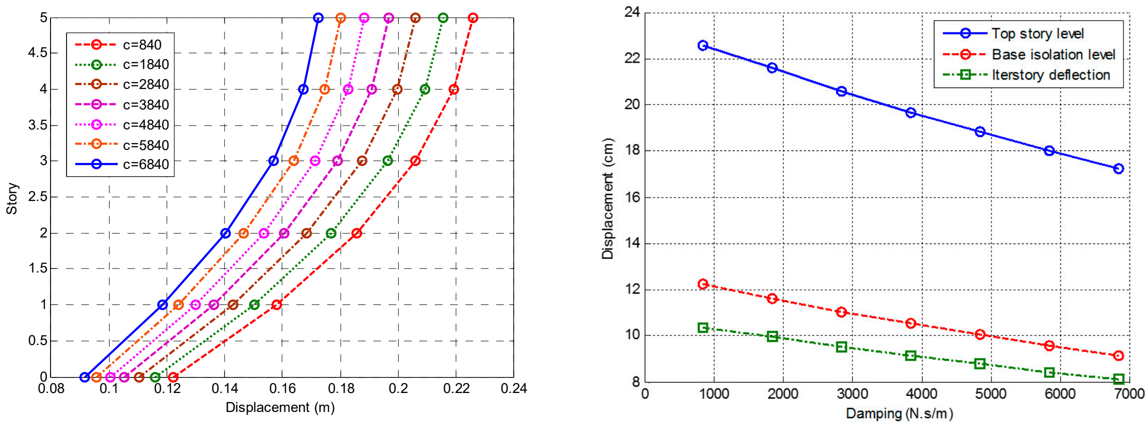


(**a**) (**b**)

Figure 13. The results of (**a**) peak displacement for the different mass of isolated base and (**b**) peak displacement at the base isolation level and top story level for the different mass of isolated base under the El Centro earthquake.

3.3.3. Changing Damping of Base Isolation

Then, in order to investigate the influence of damping of the base isolation, the parameter is changed from 840 to 6840 N.s/m, while keeping the same values of initial stiffness and mass of the isolated base. The results of the analysis in the form of the peak lateral absolute displacements for different stories of the building and various damping of the isolated base under the El Centro earthquake are shown in Figure 14a. Moreover, the peak lateral absolute displacements at the top story level and the base level as well as the interstory deflections are additionally presented in Figure 14b. It can be seen from Figure 14 that increasing damping of the base isolation caused a considerable decrease in the displacements. For example, when damping was considered to be 2840 N.s/m and 6840 N.s/m, the displacements of the base and the top story absolute displacements were equal to 11.05 cm, 9.15 cm, 20.58 cm and 17.25 cm, respectively.



(**a**) (**b**)

Figure 14. The results of (**a**) peak displacement for different damping of isolated support and (**b**) peak displacement at the base isolation level and top story level for different damping of isolated support under the El Centro earthquake.

3.3.4. Using Rubber Bumpers

The final stage of the analysis was focused on investigating the influence of rubber bumpers (see Figure 1d) so as to reduce not only relative displacements but also the absolute displacements of building. Six bumpers of a circular shape, with 15 cm of diameter and 2 cm of thickness, were considered to be installed at the isolated base (see Figure 15) providing a gap size of 4 cm. The results of the analysis in the form of peak absolute displacements and peak interstory deflections for different stories of building under various earthquakes are shown in Figure 16. Figure 16a indicates that the peak absolute displacements for the top story of an isolated building with bumpers were equal to 11.16 cm, 16.40 cm, 18.37 cm, 28.02 cm, 35.54 cm and 43.72 cm for the Kobe, El Centro, San Fernando, Parkfield, Kocaeli and Landers earthquake, respectively. That gives the reduction by 1.7%, 12.5%, 15.3%, 11.9%, 9.6% and 8.4%, respectively, as compared with the case of an isolated building without bumpers (see Figure 16a). Moreover, a comparison between Figures 16a and 2a shows that the application of base isolation together with rubber bumpers might also lead to lower values of peak absolute displacements than in the case when the fixed supports are used. It can also be seen from Figure 16b that the maximum interstory deflection occurred for the El Centro earthquake.

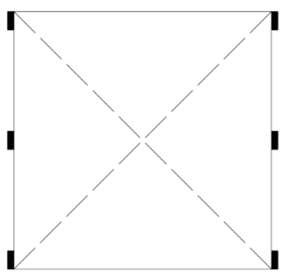


Figure 15. Plan of the building showing locations of rubber bumpers.

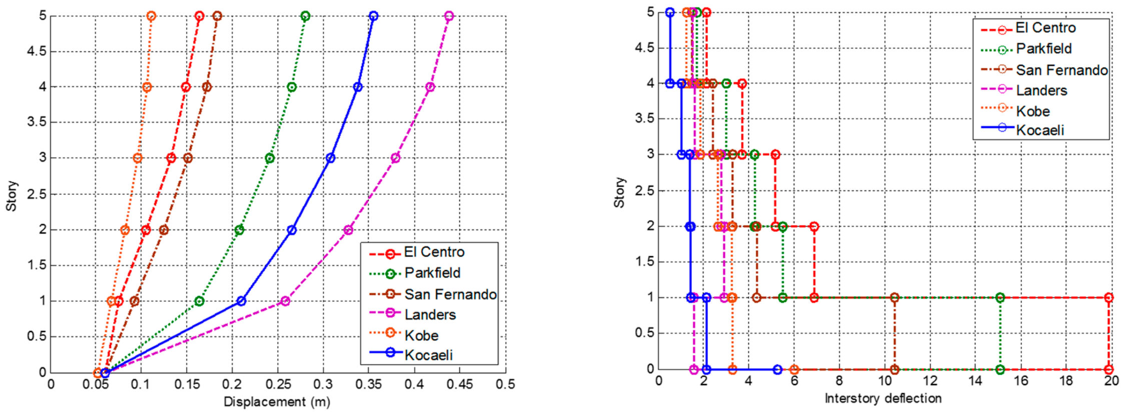


Figure 16. The results of (**a**) peak displacement and (**b**) peak interstory deflection for different stories of isolated buildings with rubber bumpers.

4. Conclusions

In this study, the effectiveness of different methods intended to decrease lateral displacements during seismic excitations was numerically investigated in order to reduce the pounding hazard between two adjacent buildings. For this purpose, a numerical elastic model of the five-story building was exposed to six different earthquake records with different Peak Ground Acceleration (PGA) values (Kocaeli, Kobe, Parkfield, El Centro, San Fernando and Landers). The height of each story was assumed to be equal to 3.00 m, which makes a total height of the structure equal to 15.00 m. The results for the top story lateral displacements and top story accelerations were compared with each other.

Firstly, the influence of the change in structural properties (story stiffness, mass and damping) was examined. When one parameter was investigated, other parameters were kept unchanged. The results for different values of the story mass clearly indicate that by decreasing story mass, the lateral displacement of stories was normally declined and the acceleration of stories was increased. Therefore, changing the story mass of structures was able to reduce the relative lateral displacement between buildings, which could be enough to avoid their pounding. The results of the analysis for different values of the story stiffness indicate that there was a decreasing trend in the lateral displacement when the story stiffness increased. Therefore, by increasing the story stiffness, the relative lateral displacement between buildings was able to decrease considerably. The results for different values of damping confirmed that the increase in damping led to a substantial reduction in structural vibrations. Therefore, as it could be expected, increasing damping led to a substantial reduction in the relative lateral displacement between adjacent structures.

In the second part of the investigation, the application of TMD, base isolation and base isolation with rubber bumpers was considered. The results of the study indicate that the lateral displacements were significantly reduced when the building was equipped with TMD. The damper reduced structural vibrations and controlled the deformations. Therefore, the method allowed us to effectively reduce the relative lateral displacements between buildings and thus prevent pounding. The results of the analysis focused on the base isolation system show that the absolute lateral displacements were larger than the values calculated for the fixed support model. However, the application of the isolation system led to a significant reduction in the interstory deflections.

A comparative summary of all methods reducing pounding hazard was presented in the final part of the paper and a comparative discussion was carried out. The results of the study show that the change in the structural properties was effective, i.e., decreasing the story mass or increasing the story stiffness and damping was able to reduce peak lateral displacement of the building and thus reduce relative displacements between neighboring buildings preventing their pounding. Among them, decreasing story mass was found to be the most effective approach. On the other hand, in the case of building with additional devices, the results were even more satisfactory. It follows that, after a detailed investigation on TMD and base isolation system, both approaches were capable to decrease relative lateral displacements and also control interstory deflections. However, the results of comparative analyses clearly indicate that using base isolation, with the addition of bumpers, could be selected as the best method to control building deflections and decrease absolute lateral displacements between two buildings so as to prevent their pounding during earthquakes.

The simplified lumped mass multi degree-of-freedom model of the five-story building was considered in the study described in the present paper. The way of designing the analyzed structure according to the seismic code was not presented nor verified herein, while the properties of the structure were used in the investigation. Therefore, further studies are required so as to fully verify the methods able to control interstory deflections for different types of buildings designed according to the seismic code, buildings with various plan arrangements and values of story stiffness and mass. In the case of such structures, more detailed structural models, including incorporation of their possible nonlinear behavior, should be used in the analysis. Further investigation should also include the detailed analyses focused on pounding between adjacent buildings equipped with different mitigation techniques intended to decrease lateral displacements during seismic excitations. That would allow us to quantify and justify the possible pounding effect in the case of different scenarios of structural configurations. Special attention should be paid to possible collisions at the top of structures, where the largest relative movements are usually observed, so as to limit the in-between gap distance separation. It should also be added that six different seismic excitations, with PGA values ranging from 307.00 to 1202.62 cm/s^2 (see Table 1), were used for the needs of the study. These records were not scaled to a specific value of PGA and thus mean values of the responses from the six earthquakes could not be directly evaluated. In order to conduct such a comparative evaluation for ground motions with scaled PGA values, further investigation should be carried out (see the example of such analysis in [12]).

Author Contributions: Conceptualization, S.M.K. and S.M.N.R.; methodology, S.M.K., S.M.N.R., H.N., R.C.B., A.J.-G. and R.J.; software, S.M.K. and S.M.N.R.; validation, S.M.K., S.M.N.R., H.N., R.C.B., A.J.-G. and R.J.; formal analysis, S.M.K. and S.M.N.R.; investigation, S.M.K. and S.M.N.R.; writing—original draft preparation, S.M.K, S.M.N.R., H.N. and R.C.B.; writing—review and editing, A.J.-G. and R.J. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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