ANALYZING THE EFFECTIVE PARAMETERS IN POUNDING PHENOMENON BEEWEEN ADJACENT STRUCTURE DUE TO EARTHQUAKE

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Abstract

Since Iran is located in one of the most earthquake–prone zones in the world, and that, once in a while an earthquake causes extensive financial and life damages and also because in large cities, tall buildings are closely constructed with inappropriate distance to provide more living space, it is of great importance to study the impact of damages caused by earthquakes. During strong earthquakes, because of different–phase oscillations of buildings with inappropriate distances, pounding phenomenon occurs. In this research, buildings with 2 to 15 stories and different heights were put together using GAP joint element, and nonlinear time–history analyses were done for Tabas, Elcentro and Sakaria accelerographs. The responses of both pounding and non–pounding cases were compared. With analyzing the results, we found out that the impact increased the responses in taller buildings but decreased them in shorter ones. The largest increase was occurred when the height difference was 3 stories. Then the effective parameters in pounding phenomenon, hardness and the distance between the structures were studied. Based on the studied of the present work, the maximum responses (lateral displacement and story shearing) caused by the pounding of two adjacent buildings, decreases in the shorter building, whereas it increases in the taller one, which may lead to critical conditions. Maximum responses (lateral displacement and story shearing) in the shorter building decreased throughout the whole height of building except for the pounding point. Maximum responses (lateral displacement and floor shearing) in the taller building increased throughout the building. Depending on the accelerograph, there are different dynamic responses and consequently different responses caused by pounding. Earthquakes with acceleration history of repeatedly changes in direction, which have higher acceleration maximums, lead to more intensive effect. One of the ways to decrease pounding effects is considering a proper distance between the two adjacent structures. This distance decreases the pounding effects; as a result, the responses will be similar to those of non-pounding case. One of the ways to decrease pounding effects is to harden the building. This change decreases the pounding effects; as a result, the responses will be similar to those of non-pounding case.

KEYWORDS: Pounding, Adjacent Structures, Earthquakes Damages, Appropriate Distance

1. INTRODUCTION

Pounding phenomenon in adjacent buildings caused to various damages during different earthquake. Pounding force is from momentum type. Existence of these forces caused that current stress overstep from design limit and in critical condition cause overturning of buildings. Usually, pounding phenomenon created from following conditions:

a- When adjacent buildings don't have enough distance from each other.
b- When buildings are far from each other, but connected by one or more members.
c- When adjacent buildings have different dynamic properties. These properties are mass, hardness, height and resistance of adjacent buildings.
d- When mass center of adjacent buildings aren't in on axial.

During strong earthquakes, adjacent structures that do not have appropriate distance and hit each other; that is called impact. The difference between dynamic properties (mass, hardness and height) of adjacent structures results different–phase oscillations which is the main cause to impact, and the more different in shape of vibration causes stronger impact and vice versa; if the dynamic properties are the same, even if the distance is zero, there is no impact. Impact phenomenon has been reported in the strong earthquakes, for example Alaska (1964), San Fernando (1971), Romania(1977), Greece (1981), Northridge (1994) and Kobe (1995). In Lumaprita earthquake (1989), most damages were caused by the impact of structure. In Mexico City earthquake (1985), more than 15% of the 330 structure that damaged or totally destroyed were result of impact phenomenon. Because of the important of this object; many researchers have reconsidered on it .

2. VARIOUS TYPES OF IMPACTS

Various types of impact seen in the recent earthquakes can be categorized into five main groups: (A) **Impact of the structure on the column of an adjacent building**: this type of impact occurs in some adjacent buildings in which the floors levels are not in the same heights. Therefore, when shaking with different phases occurs, the floor of one building hits the column of another, and causes serious damages which can lead to the fracture of the columns of the story. This type is the most dangerous impact that can result in sudden destruction of the structure. (B) **Impact of a heavier building on a lighter one**: since adjacent buildings may differ in the structural system of floors and/or in their applications, they have different masses; this can cause different phase oscillations, since the lighter building tolerates more intensive response. (C) **Impact of a shorter building on a taller one**: when two structures with different heights are adjacent, because of different dynamic properties, the shorter structure hits the adjacent one, which results in floor shearing in higher levels of impact part. It is important to know that the higher in the impact part level, the greater impact is tolerated more intensive response. (D) **Impact of two adjacent buildings with non–coaxial mass centers**: in building with non–coaxial mass centers, the structure may pound on the edge of the adjacent structure and cause strong tensional torques, which can lead to seriously damage to the column on the edges and corners of the pounded building. (E) **Pendulum–like impact of buildings**: this type of impact is usually seen in buildings, which are built completely the same (e.g. small towns). In this type of impact, some similar buildings that oscillate similarly, in strong earthquakes, hit the last building in the series and cause serious displacement in the pounded building. Existence of the same shape of the vibration in some building and the high momentum lead to last building has intensive responses. Numerous cases of this type of impact occurred in Mexico City earthquake in 1985.

3. MATERIALS AND METHODS OF ANALYSIS

For study of pounding phenomenon, 3-span concrete frames were considered that the distances of axes were 4 meter and the heights were 3.2 meter. These frames were designed with ACI-318 and 2800 (IRAN) codes. P-Δ effects weren't considered and the story floors were assumed to be rigid and the dead load and effective live load were 800 and 200 (Kg/m^2), respectively. Other characteristics of structure are shown in table 1.

Table1. Characteristics of concrete frames

F_y	4000	$(^{kg}/_{cm^2})$
F'_c	250	$(^{kg}/_{cm^2})$
I	1	-
R	8	-
A	0.35	-
Soil type	II	-

Connection modeling was done using a GAP joint element, which has only got pressing behavior (figures 1). The behavior of the element is such that it behaved nonlinearly with bilinear hardness; i. e. in cases that two adjacent buildings are in touch to each other, the hardness of this element is active and in case the two structures are separate, the hardness is considered to be zero.

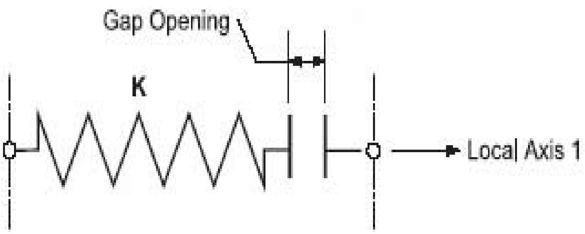
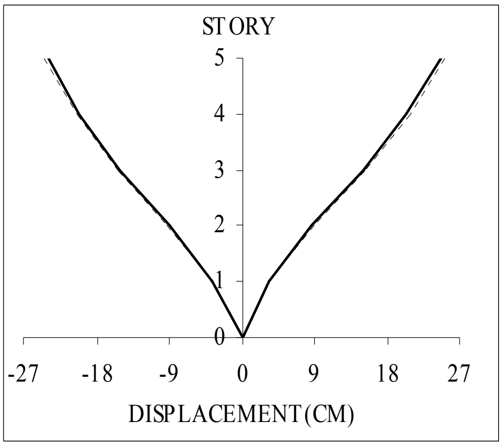


Figure 1. GAP element and its function

4. THE STUDY OF THE RESULT OF IMPACT ANALYSIS IN TWO ADJUCENT STRUCTURES

In order to study impact effect on the adjacent structure response (lateral displacement and stories shearing), modeling was done for some 2 to 15 story buildings (18 specimen), using the SAP2000 software. The analysis was done in the form of nonlinear time–history for Tabas, Elcentro and Sakaria accelerographs. The impact of a 2-story, 7-story, and 12-story building on an adjacent 5-story building under the Tabas accelerographs are presented in figures 2 & 4).



The lateral displacement of the .2 Figure
5-story building due to adjacent 2-story

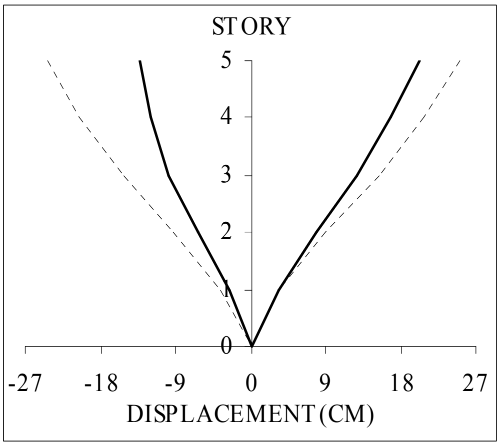
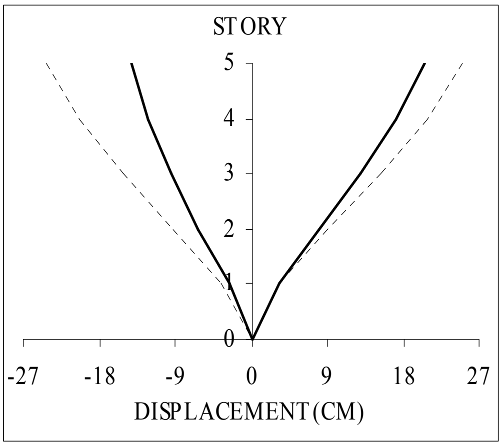


Figure 3. The lateral displacement of the
5-story building due to adjacent 7-story



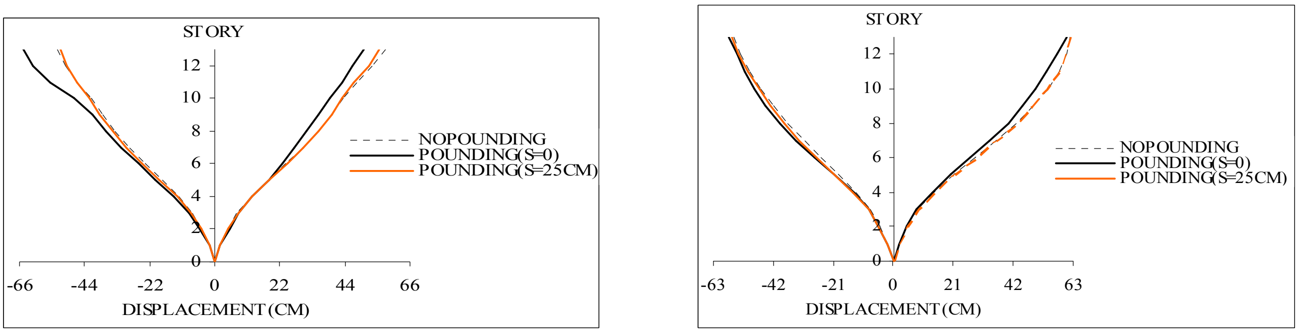
.The lateral displacement of the 4 Figure
5-story building due to adjacent 12-story

5. ANALYZING THE EFFECT OF THE PARAMETERS

To study the effect of different parameters in impact, the distance between two adjacent structures and the hardness of the two buildings are considered as the major factors. Thereby, using one of the cases which tolerated the most intensive impact effect (the model of the 10-story and 13-story buildings), the effects of the two parameters on the two structures responses are studied.

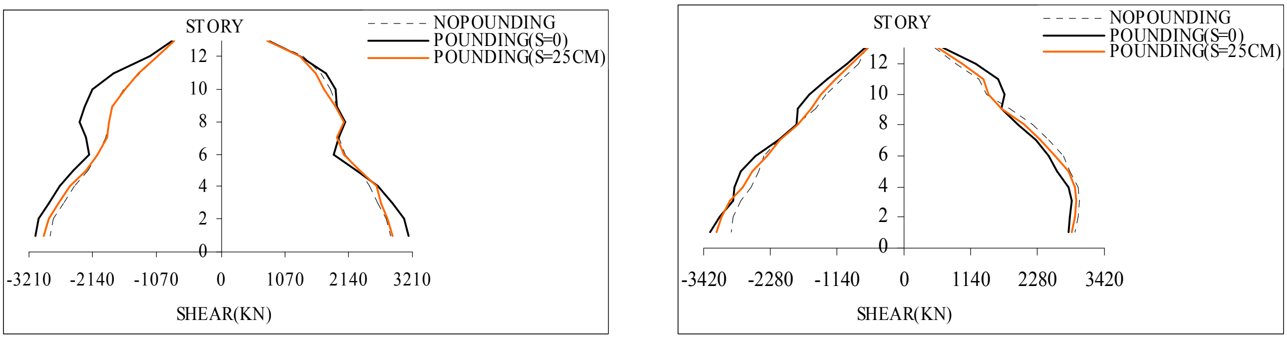
5.1. The effect of the distance between two adjacent buildings

To study the influence of this factor, the model of the 10-story and 13-story buildings was considered with a distance of 25cm. The two structures pounded on each other many times under the Tabas and Sakaria accelerographs, (while nothing was recorded under the Elcentro accelerograph). The lateral displacement of the stories in the 13-strory building, increased under the Tabas and Sakaria accelerograph, that maximum value of it was 5.57% and 10%, respectively. In this case, the responses are close to the non-impact state; such that the maximum changes in the first case (21.57%) decreased by 110.8% in the second case (-2.33%), as seen in figure 5. The shear force of the stories in the 13–story building under the Tabas and Sakaria accelerographs has increased by the effect of impacts, that maximum value of it was 3.84% and 14.62%, respectively. In this case, the responses were also similar to those of non-impact state; such that the maximum increase in the responses in the first case (35.45%) decreased by 73.15% in the second case (9.51%), as seen in figure 6. Impact force in 10 and 13- story models with 0 and 25cm distance are shown in figure 7.



A) Tabas B) Sakaria

Figure 5. The lateral displacement of the 13-story building



A) Tabas B) Sakaria

Figure 6. Story shearing of the 13-story building

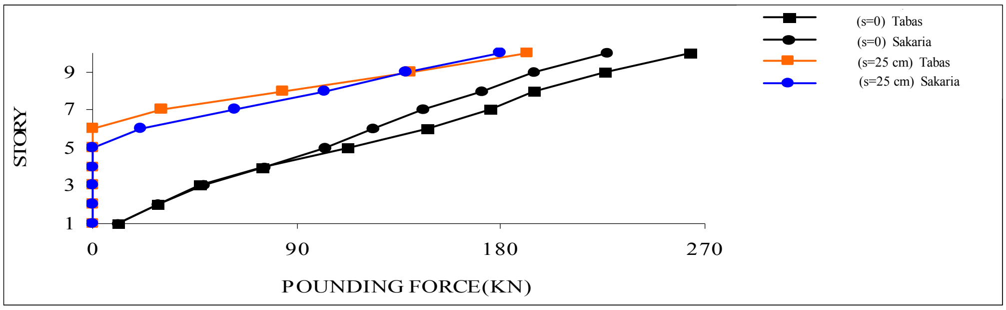


Figure 7. The impact force in 10 and 13- story models

Also the model of the 10-story and 13-story buildings was considered with a distance of 4cm under the Elcentro accelerograph. In this case, The lateral displacement of the stories in the 13-strory building are close to the non-impact state; such that the maximum changes in the first case (47.53%) decreased by 55.56% in the second case (21.12%), as seen in figure8. The shear force of the stories in the 13–story building under the Elcentro accelerograph has increased by the effect of impacts, that maximum value of it was 22.65%. In this case, the responses were also similar to those of non-impact state; such that the maximum increase in the responses in the first case (45.46%) decreased by 63.81% in the second case (16.45%), as seen in figure 9. Impact force in 10 and 13- story models with 0 and 4cm distance are shown in figure 10.

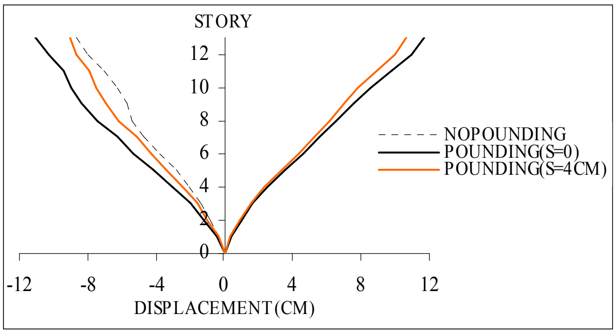


Figure 8. The lateral displacement of the 13-story building under the Elcentro accelerograph

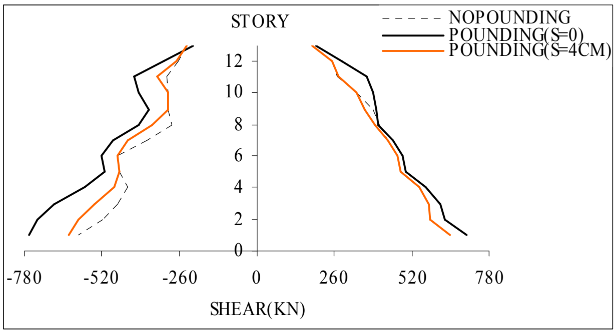


Figure 9. Story shearing of the 13-story building under the Elcentro accelerograph

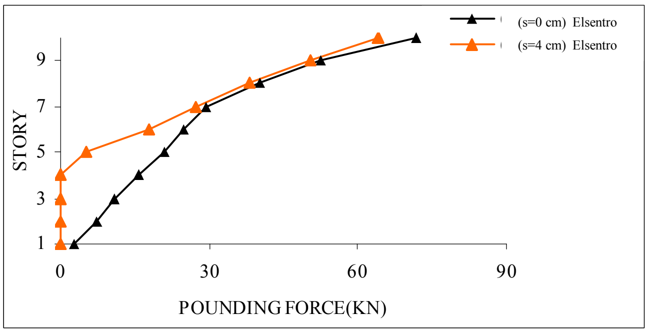
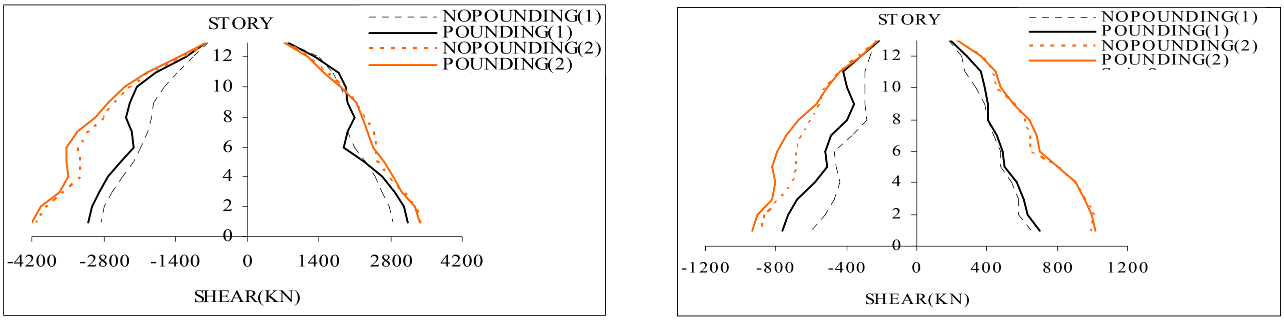


Figure 10. The impact force in 10 and 13- story models

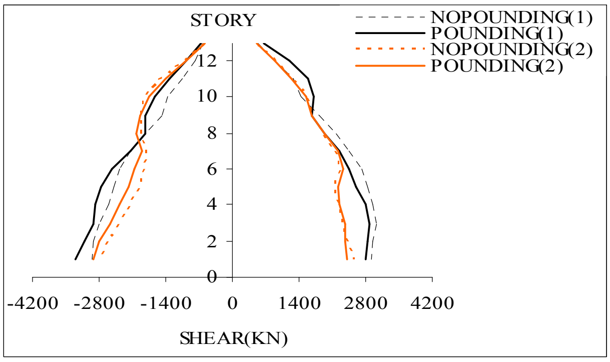
5.2. The hardness effect in two adjacent buildings

To study the effect of hardness, the same 10 and 13–story models were utilized. By hardening the taller building (13–story one) the main period decreases from T=1.79 sec to T=1.45 sec, and The responses of the two buildings are studied under the impact.

Under impact when taller building has hardened, the lateral displacement of the 13–story building increased under the Sakaria and Elcentro accelerographs, that maximum value of it was 20.13% under the Elcentro accelerograph. In this case, the lateral displacement of the stories is very similar to that of the non–impact case; such that the maximum increase of the displacement in the first case (47.53%) decreased by 76.77% in the second case (11.04%). The shear force of the stories in the 13–story building has slightly increased in lower floors, the maximum of which is 18.5% that occurred under the Elcentro accelerograph. The responses in this case were similar to those of the non–impact state; such that the maximum shear force increase in the first case (45.46%) decreased by 89.13% in the second case (4.94%), as seen in figure 11.



A) Tabas Earthquake B) Elcentro Earthquake



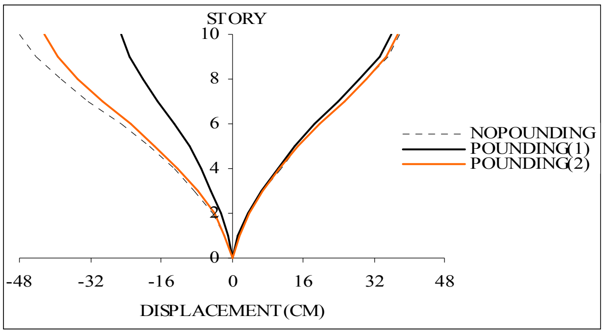
C) Sakaria Earthquake

Figure 11. Story shearing of the 13-story building

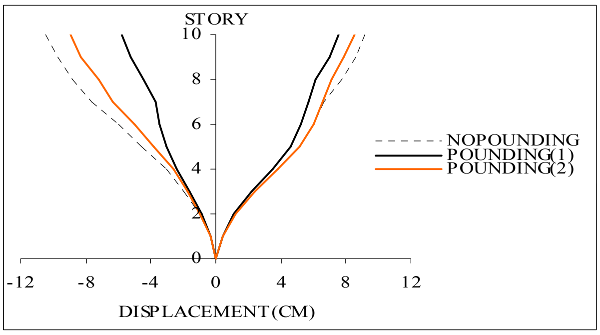
The lateral displacement of the stories in the shorter building under the Tabas and Elcentro accelerographs has decreased, the maximum of which is 18.05% that occur under the Elcentro accelerograph. The responses in this case were similar to those of the non–impact state; such that the maximum decrease in the lateral displacement in the first case (51.45%) decreased by 67.02% in the second case (16.97%). Under the Sakaria accelerograph, the lateral displacement has inconsiderably decreased throughout the whole building, but has decreased in the lower floors in positive direction; the maximum of which was 16.91%. In this case, the responses were also similar to those of the non–impact case; such that the increasing pace of the responses in negative direction in the first case changed to decreasing pace in the second case. Also in the positive direction, the increasing pace of the first case has considerably decreased; such that the maximum increase in the first case (28.92%) decreased by 41.53% in the second case (16.91%), as seen in figure 12.

The shear force of the floors in the shorter building under the Tabas and Elcentro accelerographs has decreased (except for the impact point), with a maximum of 18.69% under the Tabas accelerograph. The responses were similar to those of the non–impact state; such that increasing of the shear force in the first case (4.13%) was decreased by 58.6% to the second case (1.71%), and the maximum decrease in the shear force in the first case (44.41%) was lowered by 84.24% in the second case (7%). under the Sakaria accelerograph, the shear force of the stories has decreased throughout the whole building except for the impact point, and has increased in the lower floors in positive direction, that maximum value of it was 11.18%. In this case, the responses were similar to those of the non–impact case; such that in the impact point, increase of the shear force decreased in the first case (45.4%) was lowered by 89.73% in the second case (4.66%), as seen in figure 13.

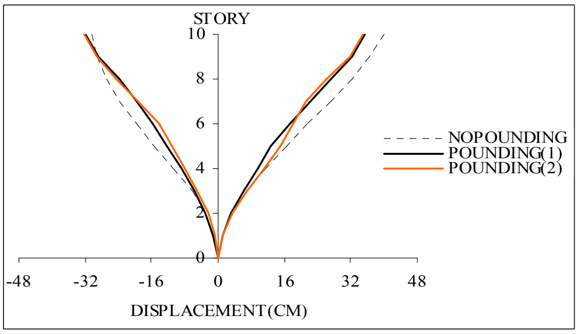
In the second case, the impact force has decreased throughout the whole building; such that the maximum impact force in the first case (263.3) has decreased by 67.89% in the second case (84.66), as seen in figure 14.



A) Tabas Earthquake

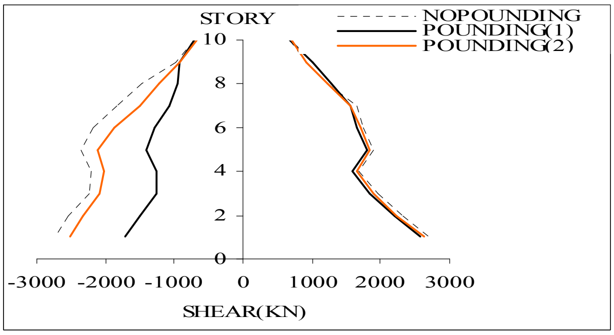


B) Elcentro Earthquake

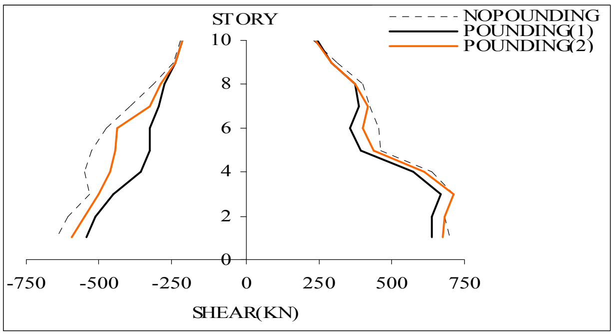


C) Sakaria Earthquake

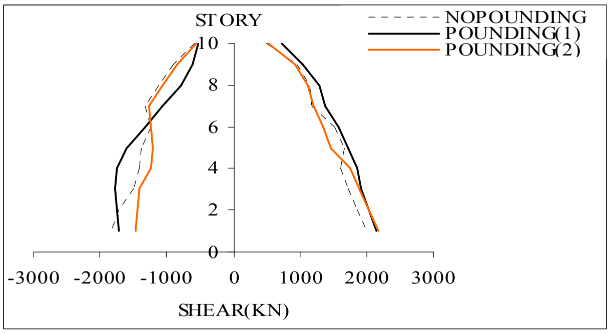
Figure 12. The lateral displacement of the 10-story building



A) Tabas Earthquake



B) Elcentro Earthquake



C) Sakaria Earthquake

Figure 13. Story shearing of the 10-story building

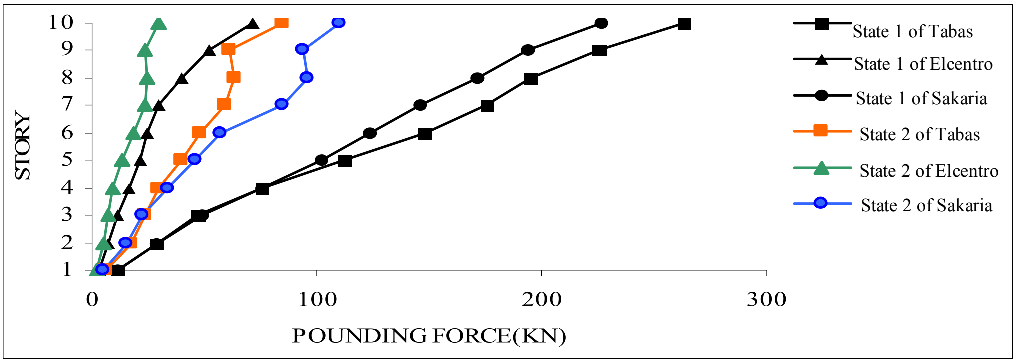


Figure14. Impact force in 10 and 13–story models

6.CONCLUSIONS

1-Based on the studied of the present work, the maximum responses (lateral displacement and story shearing) caused by the impact of two adjacent buildings, decreases in the shorter building, whereas it increases in the taller one, which may lead to critical conditions. 2-Maximum responses (lateral displacement and story shearing) in the shorter building decreased throughout the whole height of building except for the impact point. 3-Maximum responses (lateral displacement and floor shearing) in the taller building increased throughout the building. 4-Depending on the accelerograph, there are different dynamic responses and consequently different responses caused by impact. Earthquakes with acceleration history of repeatedly changes in direction, which have higher acceleration maximums, lead to more effect that is intensive. 5-One of the ways to decrease impact effects is considering a proper distance between the two adjacent structures. This distance decreases the impact effects; as a result, the responses will be similar to those of non-impact case. 6-One of the ways to decrease impact effects is to harden the building. This change decreases the impact effects; as a result, the responses will be similar to those of non-impact case.

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