Bilad Alrafidain Journal for Engineering Science and Technology
https://doi.org/10.56990/bajest/2025.040105

ISSN: 2073-9524
Pages:52-61

Analysis Experimental and Numerical of Pounding Between Two Adjacent Structures with Unequal Highs

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Abstract
Buildings nearby with different mass and heights, making it dangerous, cause the pounding to happen when two structures collide as a result of lateral movements caused by external forces. The results of an experimental and numerical analysis of pounding between two adjacent buildings are presented in this paper. To investigate two neighboring steel models, five-story and eight-story models, with different gap distances (zero-2-3) centimeters between the two steel models under ground motion during the El-Centro earthquake. To investigate how the buildings respond to pounding in experimental work using a shaking table and numerical analysis by using ABAQUS's finite element modeling software. The experimental study's findings suggest that pounding may affect a structure's response to an earthquake, especially at zero-gap. Display the results of the maximum displacement and acceleration for various gap distance reductions in value at (2-3) cm there's no pounding. The difference in displacement and acceleration outcomes between theory and experiment El-Centro earthquake at zero-gap, that's displacement, and acceleration at five-story for the five-story model is about (1%, 14%), and for the eight-story model is about (3%, 4%).

Keywords: Pounding, Earthquake, Experimental, Numerical, Shaking table, Gap, Steel model.

***Article history: Received**: 24 Sept 2024; **Accepted**: 24 Oct 2024; **Published**: 15 Mar 2025*

1. Introduction

Many instances of damage resulting from nearby structures colliding during earthquakes have been recorded. For example, after the Athens earthquake, significant damage and roof parapet collapse were noted because of the collision between the educational [1]. Following the earthquakes in Mexico City and San Fernando, there have been multiple reports of collisions between nearby structures [2] and [3]. Furthermore, following the Loma Prieta earthquake, more than 200 collisions were found to have impacted 500 buildings within a 90-kilometer radius of the epicenter [4]. Small distances between nearby structures can cause little damage or even collapse, according to observations made during multiple post-earthquake studies [5].

A similar phenomenon was noted in Nepal following the 2015 Gorkha earthquake. Several groups and organizations conducted the reconnaissance survey [6-9], but none of these reports gave pounding incidences much attention; instead, they were mentioned in passing. At 11:56 a.m. local time on April 25, 2015, a catastrophic earthquake struck central Nepal. Numerous powerful aftershocks, including the moment magnitude (MW)= 7.3 aftershocks on May 12, 2015, occurred shortly after the initial earthquake shock. Almost 9,000 individuals lost their lives because of these earthquakes in Nepal and the surrounding nations. During the earthquake,

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almost 800,000 houses suffered significant damage or collapsed entirely [10].

Buildings are constructed with little space between them because they are erected so near to one another. Because of the ground motions brought on by earthquakes, these buildings start to vibrate and may eventually collapse. These collision phenomena are referred to as "pounding". "A behavior known as pounding happens when two structures collide as a result of lateral movements caused by external [11].

A typical example of a collapsing building colliding with an adjacent building is depicted in Fig. 1. As can be seen, the floor diaphragm of the collapsed building struck the nearby RC structure during the second-story column, causing damage to the building that was comparable to mid-column pounding. The damage caused by the collision of the collapsed adjacent structure could not have been avoided, not even with a considerable gap between the buildings [12].

(A) Impact from a collapsing building

(B) Damage detail

Fig. 1 The damage caused by the collision of the collapsed adjacent structure [12].

The pounding occurred due to a different mass and highs between adjacent buildings. To investigate the pounding in nearby structures by using shaking table tests on two scaled building models, this study examines the pounding phenomenon, It is found that the peak displacements in the adjacent state are lower than those in the separate state by 4.27% for Model-1 and 22.57% for Model-2. In the time domain, a significant decrease in displacements is also seen in addition to the peaks. [13]. two multistory buildings having 15 stories and 10 stories are considered by ETABS, Both the buildings are having regular geometry dimensions of 12m X 12m. A 50mm seismic gap was used between the buildings. The maximum response decreases in shorter buildings, while it increases in taller ones. Significant pounding effects between two buildings are revealed by the investigation, which results in axial force stress states and bending moment states [14]. throughout the investigation. Non-linear ground motion analysis has been carried out on the buildings in the SAP2000 numerical platform in the aftermath of the Uttarkashi earthquake of 1991, This phenomenon has the potential to cause damage to the buildings in various forms, such as collapse or cracks [15]. Also, to investigate the impact of neighboring structure collisions during an earthquake (EL-Centro), the investigation was conducted with varied nearby structure heights (4,6,10) and gap sizes (1-2) cm, finding the pounding results in a significant increase due to a difference between buildings [16]. A study involving 3-, 5-, and 9-story adjacent, the pounding finding decrease when increase the gaps [17].

Seismic pounding causes the building to experience acceleration of up to 30% and an increase in story displacement of up to 80% [18].

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So, in previous studies, take just a numerical and with a few experimental studies with a single panel and a little height.

In this study, experimental and numerical analyses of pounding of two adjacent steel models with different mass, highs, and gaps are performed on a shaking table (1x1.4) m at the University of Diyala College of Engineering, subjected to earthquake ground motion (El-Centro 1945).

2. The experimental model properties and setup

Scale-down 1/15 five-story and eight-story steel replicas were built specifically for the experiment and utilized as test subjects, as shown in Fig. 2, at two different heights of 1500 and 2400 mm. They were all built with four floors per story, each measuring 300 mm by 300 mm overall and having a 1 mm thickness, connecting bolts for the beams and columns. The columns were placed 300 mm apart in a rectangular configuration around the shaking table. Each story rises 300 mm, and the beam column has a square cross section (20 x 20) mm with a length of 300 mm. Ceramic tiles measuring 300 by 300 mm were attached to the steel of each floor, with a thickness of 12 mm, to replicate the mass of the models. And was used weight W=5kg a thickness t=10 mm, with a dimension of 265 x 265 mm. as shown in Fig. 3.

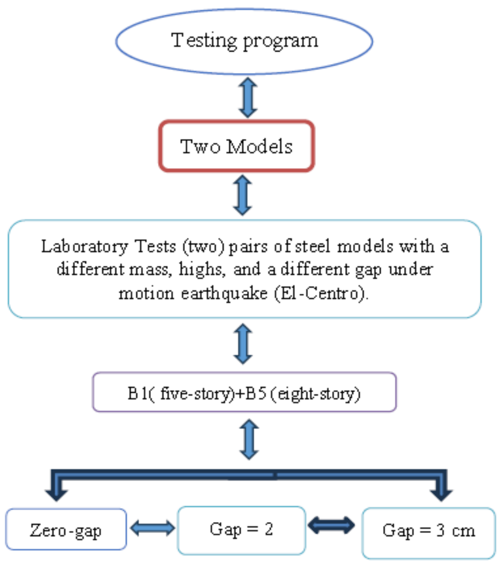

Fig. 2 The Flow chart of experimental work.

Fig. 3 Two steel models, five-story and eight-story, on a shaking table at zero-gap.

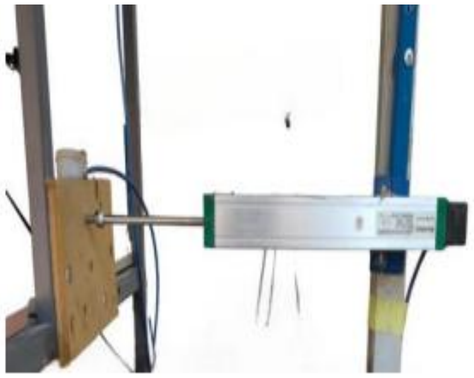

Fig. 4 A accelerometers GY61W and a linear variation displacement transducer (LVDT) with 220 mm.

2.1 Testing of Models

Following the experimental models' placement on the shaking table at zero gaps, the displacement transducer (LVDT) and the accelerometer sensors (GY-61W) are displayed in Fig. 4. The five-story and eight-story adjacent steel models have varying highs and gaps (0-2-3) cm. The sensors were placed in the manner shown in Fig.3; On the third and eighth, of the right and left models, type a) accelerometers GY61W and a linear variation displacement transducer (LVDT) with a 220 mm variety were mounted. On the base of the shaking table depicted in Fig. 5 (a, b), one type of GY-61W accelerometer and one LVDT with a 500 mm variety were mounted.

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2.2 Earthquake test

Under the El-Centro earthquake of 1945, shaking table tests were conducted using earthquake ground motions Fig. 6. The model is then set up for inspection by being placed on the vibration table. Next, the sensor device that gathers and stores the data from the inspection is turned on, and the earthquake ground data is uploaded to the device program. Subsequently, the device program receives an operating command, which transforms the tremor data into commands. The table moves first, starting the servo motor to begin simulating an earthquake. The results are then archived and scrutinized.

Included tests of two five-story adjacent steel models with different masses and gaps. Two model structures were placed on the shaking table to record the dynamic response of displacement and acceleration. There is enough space between the test structures to record the dynamic reaction. The separation distance between the two models is (0-2-3) cm.

(A) The displacement sensors (LVDT) (with a range of 500 mm).

(B) accelerometer sensors.

Fig. 5 The displacement sensors and accelerometer sensors.

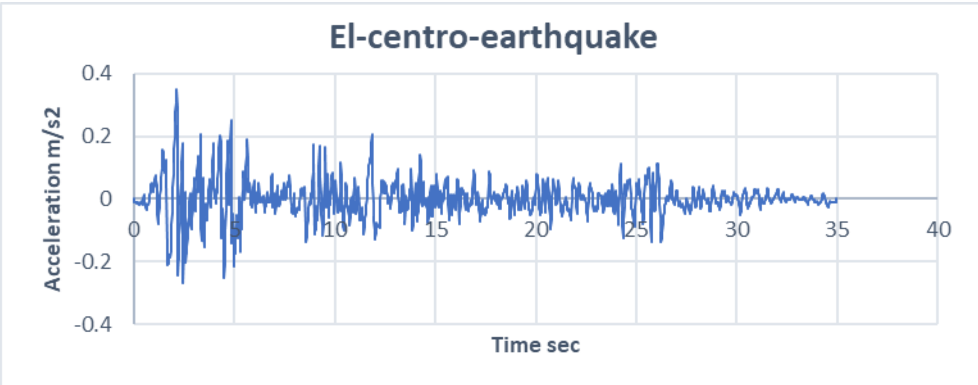

Fig. 6 Time history of earthquakes

3. Finite Element Analysis

In the second phase of the investigation, a numerical analysis was conducted using finite element modeling by software in (ABAQUS). Along the axis is (U1) unconstrained in three-dimensional (3D) dynamic contact analysis, with six degrees of freedom per node. All supports were considered to be fixed, and finite element models of the frames' underground motion during earthquakes were created. The simulation was performed in close proximity to the prototypes. By employing a finite element as a shell element on each side of the tube, the beam-column was represented as a tube. Ceramic was used to replicate the mass of the models and was affixed to the steel plate diaphragm of each floor. The element's dimensions are identical to those of the experimental model.

Fig. 7, the material of all parts is steel, just ceramic as mass like concrete illustrates the material

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parameters of all steel elements, which include a mass density of 7.85E-09 N/mm, a poison's ratio of 0.3, and a Young's modulus of 200,000 N/mm. With a mass density of 2.7*E-9 N/mm, a poison's ratio of 0.2, and Young's modulus of 23900 N/mm, the mass is representative of a ceramic.

4. Results and Discussion

This section shows the results achieved from the laboratory work and finite element model by using (ABAQUS) software. As shown in Fig. 8, the displacement and acceleration that were attained by shaking table, and in Fig. 9, the displacement and acceleration that were attained from the finite element model in (ABAQUS) software, for different gaps under the ground motion excitation utilized, are El-Centro 1945.

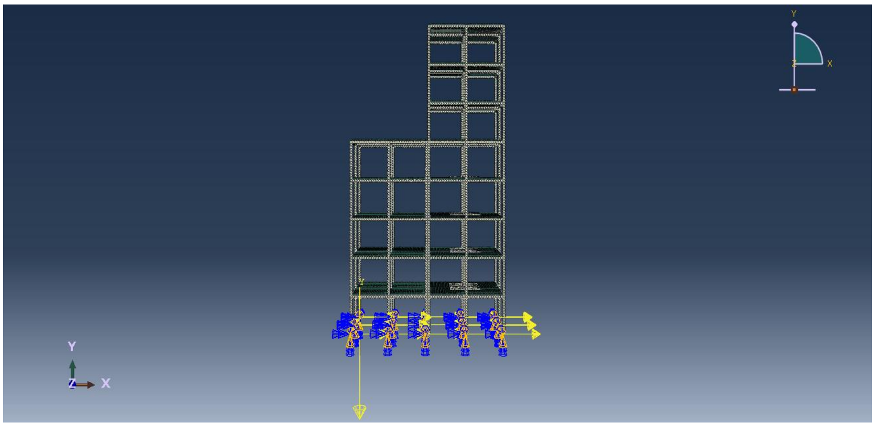
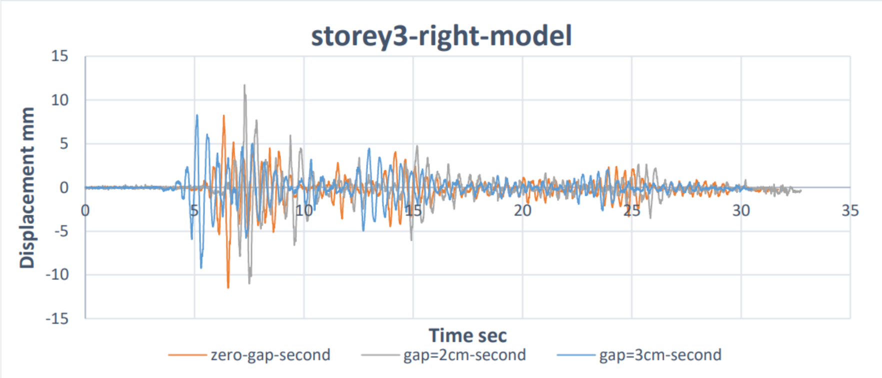
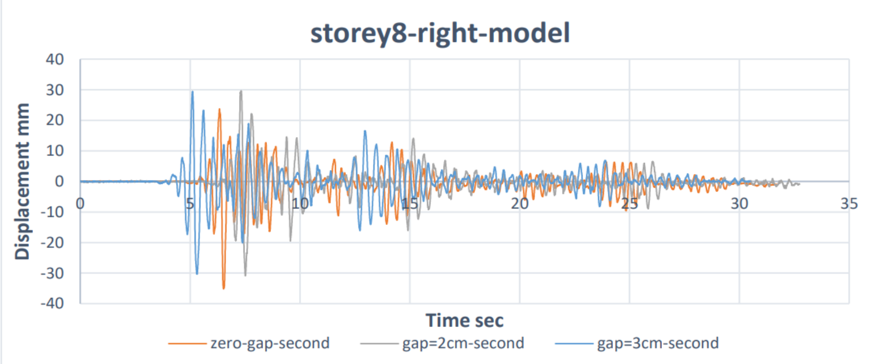


Fig. 7 Finite element model in (ABAQUS) software.



a) Displacement



b) Displacement

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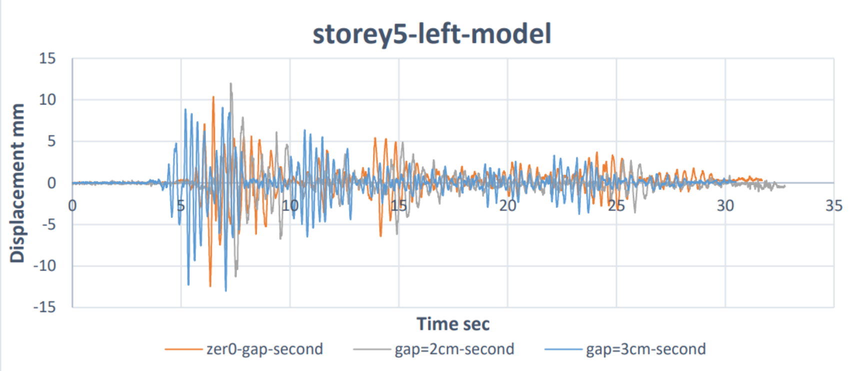
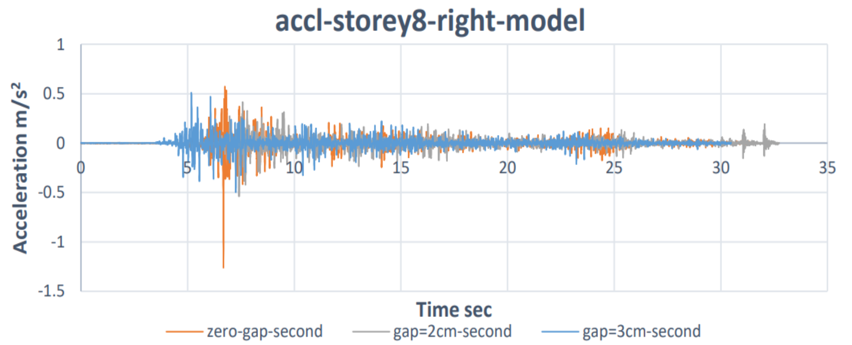
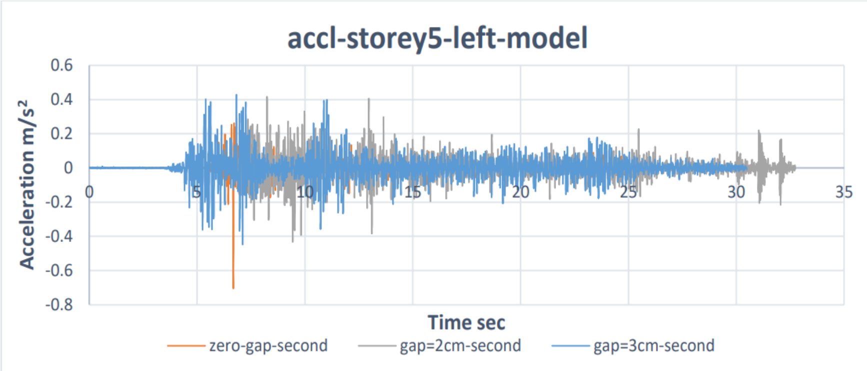


c) Displacement

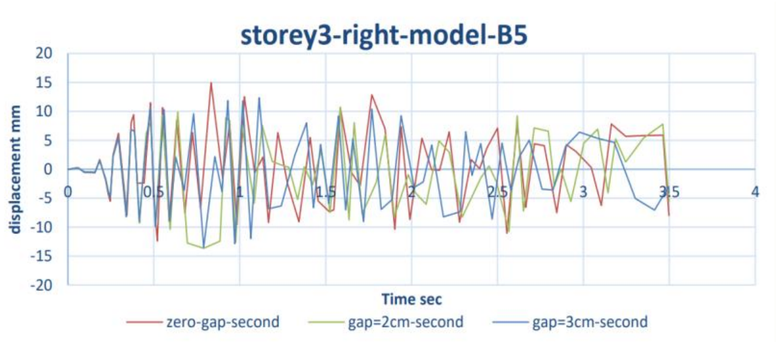


d) Acceleration



e) Acceleration

Fig. 8 The displacement and acceleration at story three, story eight-right (B5) model, and at story five-left(B1) model, under El-Centro earthquake.



a) Displacement

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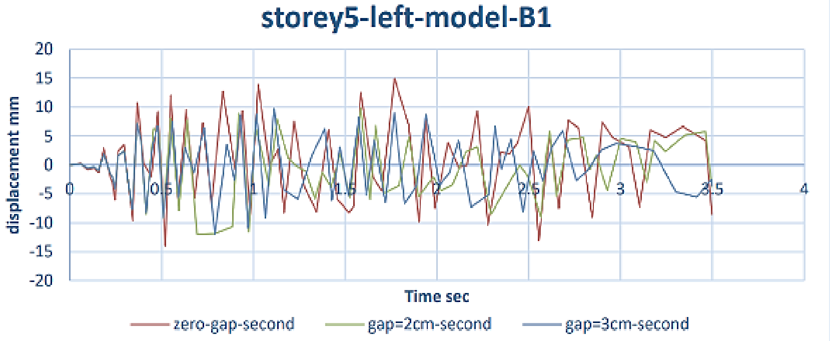
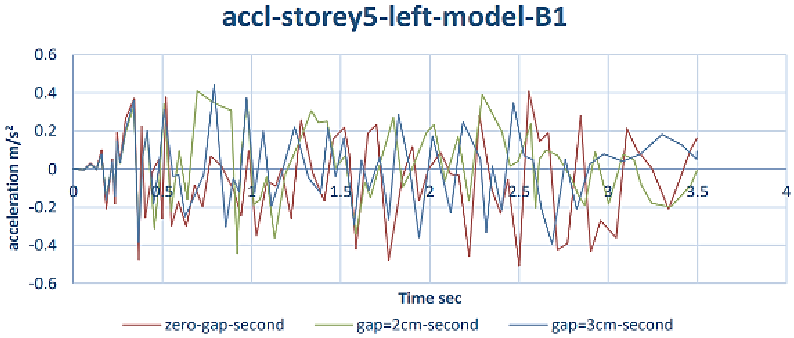
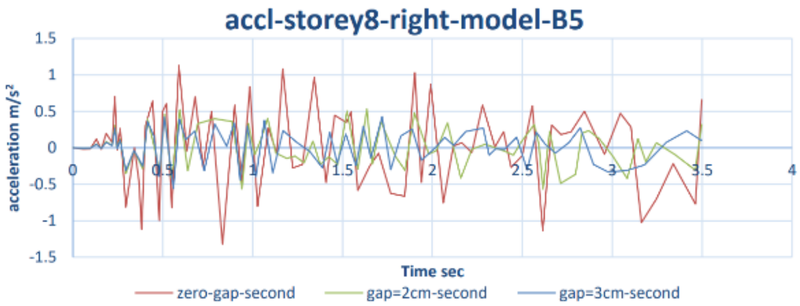
b) Displacement



c) Displacement



d) Acceleration



e) Acceleration

Fig. 9 The acceleration at stories (three, five, and eight) under El-Centro earthquake.

The results of a comparison between experimental and numerical research show that pounding affects a structure's responsiveness to earthquakes. Table (1) displays the experimental and numerical results of the maximum displacement and acceleration for different gap

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distances. The pounding causes displacement responses and acceleration at different story levels in the case of zero gap distances that are greater than those from the separation distances (3-2) cm and pounding occurred at zero gaps. The value started to decrease with the increased distance between the two models. The results were the following:

1- In the experiment, the peak displacement at story three was reduced by 10%.
2- Theoretically, the peak displacement at story three was reduced by 13%, and acceleration at story three was reduced by 5%.
3- In the experiment, the peak displacement at story eight was reduced by 9%, and the acceleration at story eight right model was reduced by 48%.
4- Theoretically, the peak displacement at story eight was reduced by 9%, and the acceleration was reduced by 57%
5- In the experiment, the peak displacement at story five was reduced by 16%, and the acceleration at story five reduction 37%.
6- In theory, the peak displacement at story five was reduced by 14%, and the acceleration reduction by 14%.

Table 1: Peak displacement and acceleration for two models under El-Centro earthquake.

a) Displacement-mm (B1+B5)

	Zero-gap		Gap=2cm		Gap=3cm	
	Experimental	Theoretical	Experimental	Theoretical	Experimental	Theoretical
Storey-8-right	34	34	31	31	31	31
Storey-5-left	14	14	12	12	11.7	12
Storey-3-right	14.5	15	13.5	14	13	14

b) Acceleration-m/s^2 (B1+B5)

	Zero-gap		Gap=2cm		Gap=3cm	
	Experimental	Theoretical	Experimental	Theoretical	Experimental	Theoretical
Storey-8-right	1.25	1.3	0.52	0.56	0.52	0.56
Storey-5-left	0.7	0.51	0.44	0.44	0.44	0.44

Pounding might result in considerable overstresses in the building with the smaller mass if there are significant mass differences. Because of the potentially significant disparities in total mass and periods, pounding can cause major issues when there are neighboring buildings that are not of comparable height. El-Centro showed a reduction in collisions between the two models at 2-3 cm and a decrease in value as the distance between the two buildings increased without any pounding.

5. Conclusion

Two steel models, with a distinct gap under the ground motion excitation in the El-Centro 1945 earthquake, were used in this paper's five-story and eight-story analyses. For searching at the reactions of the buildings to earthquakes due to pounding. According to the results of the experimental investigation, pounding could have an impact on a structure's reaction to an earthquake. Display the maximum displacement and acceleration results for various gap distances. When there is no gap in the space between two buildings.

A collision has occurred between the two nearby buildings. Both acceleration and displacement increase because of the pounding; therefore, the pounding occurred due to a different mass, and highs between two adjacent models caused the model to vibrate out of phase in a different direction, causing collisions between the models. But no pounding occurred at gaps (2-3) cm. It may be shown that finite element analysis agrees with experiment results and provides approximations for experimental analysis. The difference in displacement and acceleration outcomes between theory and experiment El-Centro earthquake at zero-gap, that's displacement, and acceleration at five-story for B1 is about (1%, 14%), and for B5 is about (3%, 4%).

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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