Republic of Iraq
Ministry of Higher Education
and Scientific Research
University of Diyala
College of Engineering
Department of Civil

Seismic Pounding Behavior of Adjacent Multi-Story Buildings in Iraq

A Thesis Submitted to Council of College of Engineering, University of Diyala in Partial Fulfillment of the Requirements for Master Degree of Science in Civil Engineering– Structural Engineering.

BY

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2025 A.D **1446 A.H**

Abstract

Buildings begin to vibrate due to ground movements caused by earthquakes, and they may collide with each other. The term "pounding" refers to this phenomenon of collision. Pounding occurs when two buildings collide due to lateral ground motions.

In this research, a 1/15 scaled model was used, consisting of two adjacent steel models: a five-story building with a height of 1500 mm and an eight-story building with a height of 2400 mm. Each model has different mass, height, and gap distance (0, 2, 3 cm). These models were subjected to different ground excitations (Kobe, El-Centro, and Ali-Gharbi). The study aimed to understand how buildings respond when subjected to collision-induced effects due to earthquakes.

The study consists of two parts: the first part is an experimental study where two steel models were tested in a laboratory using a shaking table with a size of (1 × 1.4 m) at the University of Diyala, College of Engineering. The second part is a numerical simulation of the two models using the Finite Element Method with ABAQUS v.2021 software.

During the study, it was observed that when the gap distance was 3 cm, the displacement and acceleration values decreased due to the presence of the gap between the models, which reduced the pounding. Pounding causes an increase in acceleration and displacement, especially when there are differences in height and mass between the buildings.

To compare with a single isolated model, at Kobe earthquake, for five-story model at story five increased by 94%, 42% respectively. For eight-story model, at story eight increased by 5%, 46% respectively. At El-Centro earthquake, for five-story model at story five, increased by17%, 15%, for eight-story at story eight increased by 7%, 34%, for five-story model at story five increased by 5%,13%, for eight-story model at story eight increased by 80%, 14% at Ali-Gharbi earthquake.

Chapter One

Introduction

1.1 General

Earthquakes produce sudden ground motion and vibrations, which are transmitted through the foundation from the earth to the superstructure (Chopra, 2012). In general, earthquakes are considered unpredictable natural phenomena, despite numerous research efforts aimed at explaining them. Earthquakes can severely damage newly constructed buildings. During earthquakes, buildings experience dynamic motion. Moreover, the building is subject to forces known as inertia, which oppose the acceleration caused by seismic excitations. It is typical to assume external forces on the building in order to manage these inertia forces, also referred to as seismic loads. Since inertia forces and earthquake motions vary with time and direction, seismic loads are not constant in space or time.

Moreover, the earthquake in Mexico on the 19th of September 1985 provided an opportunity to learn more about how steel structures respond to intense seismic stimulation (Martinez-Romero, 1987). Many medium-rise steel structures were damaged, raising numerous questions about the behavior and response of steel buildings during earthquakes. Similarly, during the Kobe earthquake in 1995, 988 steel structures were damaged, with eighty percent of them being buildings with fewer than five stories (Horikawa et al., 1996).

1.2 Seismicity in Iraq

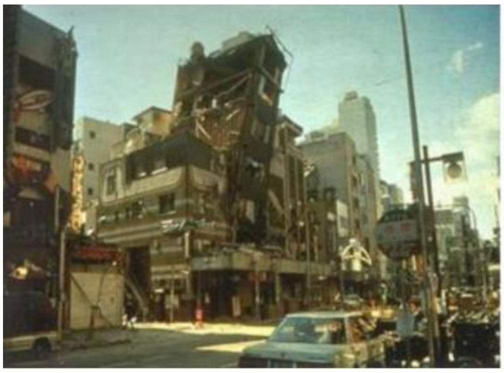
Iraq's recent seismicity after 1900 A.D. relied on data from seismic world stations, modern seismicity is thought to be more accurate than historical information. Most of the country's shocks are crustal depth shocks, with magnitude ranges of 2.7 to 7.2 better recognized after 1900 (Alsinawi, 1975). Iraq's seismic activity is somewhat connected to the country's current tectonic activity, which suggests that the seismicity is undoubtedly tied to movements of crustal blocks. Recent research validates these conclusions. The seismicity research used earthquake data from 1900 to 1988. The largest earthquakes were recorded by the Iraqi Seismological Network (ISN). Although Khanqeen earthquake was the largest earthquake happening in middle and south of Iraq with ML =5.6 magnitudes, and also Ali-Gharbi in maysan ML =4.9 magnitudes.

Due to Iraq's exposure to seismic risks and the damage to some buildings constructed due to these recent earthquakes, the buildings are subjected to lateral movements that may lead to collision between buildings, and this phenomenon known as "pounding." The pounding of adjacent buildings can be very dangerous because adjacent buildings have different dynamic characteristics or different high or different level story during earthquake. Thus, cause damage due to insufficient gap to buildings their lateral movements. Since current regulations of municipalities in Iraq allow the use of the whole width of the lands in buildings which will lead to direct touch between adjacent buildings.

1.2.1 Pounding

Buildings are often built in close proximity to each other. For example, Iraq, particularly its large, densely populated cities. Adjacent buildings are built in close proximity each other, leaving no space between them. These buildings begin to vibrate as a result of ground motions caused by earthquakes, and they could collide. The expression "pounding" refers to this collision phenomena. "A phenomenon known as pounding occurs when two buildings collide as a result of lateral movements brought on by outside forces" (Raheem, 2013). According to (Khatiwada et al, 2011), "seismic pounding is defined as the collision of adjacent buildings during earthquakes."

The pounding between adjacent building is commonly observed after every strong earthquake, however the collision causes impacting location, in an extreme case, cause the structure to collapse. For example, pounding between adjacent building and bridge structures was also reported after the 2011 Christchurch earthquake (Cole et al. 2012; Chouw and Hao 2012). Rosenblueth and Meli (1986) in Mexico earthquake reported 40% of damaged structures, and in 15% of the cases, pounding was identified as the primary reason for the structural collapse. However, this estimate of pounding damage was later reported to be an overstatement (Agnostopoulos and Karamaneas 2008). Kasai and Maison (1997) reported more than 200 cases of pounding occurrences during the Loma Prieta earthquake and the related collapse of some buildings. Furthermore, there are significant variations in the masses, periods, or heights of the relevant buildings, pounding becomes more noticeable. There was show of pounding damage during earthquakes in van earthquake in 2011. And buildings damage due to Kobe in 1995 earthquake. As shown in Figure (1.1).



a b

Figure 1.1: (a) Buildings damage due to Kobe in 1995 earthquake (Abdelnaby, 2012), (b) The pounding damage in a different height under the van earthquake 2011 (AbdelRaheem,2019).

The most straightforward and effective method to mitigate pounding and minimize the resulting damage is to provide sufficient separation between adjacent buildings. By reducing lateral movement, the impact of pounding can be significantly lessened (Abdel Raheem, 2006; Jankowski, 2007; Anagnostopoulos, 1988; Chau and Wei, 2001; Ruangrassamee and Kawashima, 2001).

1.3 Problem Statement

Seismic pounding occurs when adjacent buildings vibrate out of phase during an earthquake due to differences in mass and height, and the distance between the buildings is insufficient to accommodate their lateral movements. In addition to the increase in seismic activity in Iraq, there is a rise in the construction of adjacent high-rise buildings, which leads to the danger of collisions between them during earthquakes. This phenomenon can cause significant structural damage, affecting the stability of the buildings.

1.4 Objectives

Experimental investigation of prototype steel models and numerical simulation using finite element (ABAQUS) software to understand the behavior and the pounding effect between adjacent buildings under actual earthquakes, and to investigate the sufficient distance between buildings to reduce the damage caused by pounding during seismic events.

1.5 Study Methodology and Variables

To investigate the performance of two adjacent steel buildings, the study was done by testing two adjacent steel buildings with different heights, masses, gaps, and under a different earthquake motion on a seismic shaking table of size (1X1.4) m, at the University of Diyala College of Engineering, subjected to earthquake ground motion to study and understand pounding behavior, and using finite element modeling by the software ABAQUS for two adjacent steel buildings. These parameters were:

1- Different high buildings in experimental work (five- and eight-story), and using finite element modeling by software ABAQUS.
2- Different mass by use (5 kg and10 kg).
3- Gaps (0, 2, and 3 cm).
4- Different earthquake motions (Kobe, El-Centro, Ali-Gharbi).

1.6 Outline of Thesis

This thesis is divided into six chapters a brief description of each chapter contents is presented below:

1.Chapter One: Introduction about earthquake, description of seismic pounding, with explanation a problem study and objectives of study.

2.Chapter Two: Provides a brief literature review on experimental and theoretical study of steel building subjected earthquake loading.

3.Chapter Three: It describes the specifications of the steel models used of five-and eight-story with a different high, mass, and different gap, under a different earthquake motion are (Kobe, El-Centro, and Ali-Gharbi), as well as an explanation of the devices used in the tests.

4.Chapter Four: This chapter include the parametric study of the response the five-story, and eight-story with discussion all the results.

5.Chapter Five: Finite element method program (ABAQUS version 2021), to simulate the five-story, and eight-story of steel models subjected to a different earthquake motion, with all the results are obtained of finite element method program (ABAQUS version 2021).

6.Chapter Six: Conclusion and recommendation.

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وهي جزء من متطلبات نيل درجة الماجستير في علوم الهندســة المدنيــة-هندسة انشائية

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1446هـ 2025م