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The Behavior of Pile Foundation Surrounded with Rubber-Binder Mixture Under Seismic Loading

A Thesis Submitted to the Council of the College of Engineering, University of Diyala in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering-Soil and Foundation Engineering

By

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CHAPTER ONE

INTRODUCTION

1.1 General

A wide range of related fields and sciences, including applied mechanics, geology, soil and rock dynamics, and seismology, are involved in the design and study of a foundation system. Therefore, in order to produce safe and economical designs, foundation engineers must keep up with the latest developments and technological advances in these areas, or can seek competent advice in these areas. There is still more work to be done in developing protocols to evaluate the seismic bearing capacity of shallow and deep foundations as well as the permanent displacement induced by earthquakes in these types of constructions. Simple and uncomplicated procedures are needed, which can be derived or developed from laboratory modeling that can accessed to produce the seismic response of perfectly manufactured prototypes (Romo, 2000).

Recent seismic activity linked to catastrophic earthquakes in numerous parts of the world draws attention to the significance of pile foundations and how they affect how supporting structures react. Despite the significance of static loading in pile foundation design, dynamic loading continues to pose the biggest challenge because it exerts additional forces, such as axial and lateral forces, on the pile foundation (Bentley, 1999).

When designing structures that are subjected to earthquake loading, the lateral load capacity of pile foundations plays a crucial role. Engineers designing closely spaced pile groups have very little information to work with, despite the fact that useful methods have been developed for predicting the lateral capacity of single piles under static loads. Due to the significant challenges and high costs associated with conducting lateral load tests on pile , there are comparatively few full-scale load test results that display the distribution of load within a pile (Rollins et al., 2003).

Comparatively speaking, the response of pile foundations under dynamic loading is more intricate than that under static loading. Regretfully, little is known about how well pile foundation systems perform under cyclic loads or during earthquakes (Prusty, 2010). One of the primary crucial issues in the dynamic analysis that requires further understanding is the interaction between the soil, pile, and foundation. Unfortunately, due to the challenges in conducting such tests involving the

numerous variables related to both soils and piles, very little information is available on the observed dynamic behavior of pile foundations (Heggond and Chougale, 2015).

The behavior of structures based on deep foundations (piles) under earthquake loading is an important factor affecting the performance of these foundations. It has become necessary to study how to reduce these seismic disasters and delay the failure time of buildings to give more time to evacuate buildings and thus maintain people's safety. Most of the damping methods adopted in earthquake-resistant structures depend on treatment in some parts of the structure in order to resist the effects of earthquakes. There are few studies that rely on dampening the impact of earthquakes before they reach the foundations of structures. This study includes finding a way to dampen earthquakes before they reach the piles by using rubber and placing it around the pile. Rubber is considered one of the best dampers due to its high flexibility and ability to absorb energy. The use of rubber to reduce seismic effects is considered a type of sustainability.

The urgent need to find sound ways to dispose of tire waste in a way that is not harmful to the environment prompted the researcher to find solutions to recycle it and use it again, as the processes of burying rubber in the soil or burning it cause very great harm. Environmental damage (Mohamed et al., 2013), especially since the quantities of damaged tires are very large, reaching hundreds of millions annually. In 2005, 299 million tires were disposed of in the United States, and 103 million tires were disposed of in Japan (Soni et al., 2011). As a result, researchers and civil engineers became increasingly interested in finding technical solutions to recycle this waste. It was used as a backfill material in retaining structures, and mixed with soil due to its light weight (Humphrey et al., 1997). As a filler material (Edil et al., 1994), (Foose et al., 1996), (Zornberg et al., 2004), and investigations were conducted into the use of waste rubber to reduce vibrations on buildings in the event of earthquakes because it is one of the best damping materials (Tsang et al., 2008), (Senetakis et al., 2012), (Senetakis et al., 2012).

1.2 Statement of the Problem

Iraq is located on the northeastern boundary of the Arabian tectonic plates, and this area is considered seismically active. There is a high probability of annual seismic activities of varying strength in Iraq as evident in the seismic history of Iraq (Abdul Reza et al., 2013). Due to the increase in seismic activity during the past years and its impact on civil structures of all kinds, including deep foundations widely , the importance and necessity of understanding the behavior of piles and the behavior of structures under the influence of earthquakes and finding solutions to reduce their impact and the resulting losses have increased.

1.3 Importance of the Study

It is necessary to study the behavior of the deep foundations (piles) under the influence of earthquakes, especially since Iraq is located within seismically active areas to reduce human and property losses that result from earthquakes, as shown in Figure (1.1). A study of the effect of surrounding the piles with rubber, which is a good damper, when exposed to earthquakes, where the acceleration, speed, and displacement of the movement of buildings during earthquakes are studied when the piles are surrounded with rubber. One of the importance of this study is the sustainability of the materials as a result of recycling waste tire rubber and reusing it instead of destroying it that are harmful to the environment.

Figure (1.1) An example of damage caused by an earthquake (Kobe earthquake in 1995).

1.4 Objectives of the Study

The purpose of this research is to comprehend the following:

1.Study the acceleration and lateral displacement resulting from the movement of the top of the pile when exposed to earthquakes in the presence of rubber surrounding the piles.

2.Studying the effect of changing the location of the rubber surrounding a pile at different locations the top, middle, and bottom on the displacement and acceleration of the structure when exposed to an earthquake.

3.Studying the effect of changing the diameter of rubber surrounding a pile on the displacement and acceleration of the structure when exposed to an earthquake.

1.5 Thesis Outline

This study consists of the following five chapters:

Chapter One: This chapter includes a general introduction to earthquakes in Iraq and their impact on the deep foundations (piles) and the importance and objectives of the study.

Chapter two: covers a history of seismic acts in Iraq as well as a brief description of earthquakes and their measures. a summary of earlier analytical and experimental studies on how piles respond to earthquakes and Studies on the use of rubber waste.

Chapter three: It explains the specifications of the soil used, the waste rubber used, the devices used in the tests, the mechanism of their operation, and explains how to prepare samples for examination and how to surround the piles with rubber.

Chapter four: Presents the results of piles surrounded by rubber waste with different variables and is discussed.

Chapter five: provides the findings of this study, together with the most significant recommendations for further research.

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Abstract

Earthquakes occur naturally, are unpredictable, occur suddenly, and because of their violent movement, have the potential to cause significant damage to structures. Due to the increasing impact of earthquakes that have recently escalated in Iraq on all types of civil facilities, especially those based on piles, it has become necessary to conduct a study on the impact of earthquakes, and because traditional seismic isolation methods for buildings are very expensive. This study aims to reduce the seismic effect on single pile in sandy soil.

The research program includes studying the behavior of a single pile in sandy soil surrounded by recycled rubber from old tires. The study also included a group of variables that were studied, including the diameter, length, and location of the rubber surrounding the pile, including three groups. The first group represents placing the rubber around the pile at the top of the pile. The second group represents placing the rubber around the pile in the middle part of the pile. The third group represents placing the rubber around the pile at the bottom of the pile. Three different diameters of rubber were taken in all groups (three, five and seven times the diameter of the pile) and two different lengths of rubber (5 and 15) cm. Experiments were conducted practically by simulating the Kobe earthquake on models using a shaking table device.

The results of laboratory experiments indicate that surrounding the substrate with rubber works very efficiently, as it reduces the impact of earthquakes on the structures. Comparison between the results of the models tested under seismic load showed that the lateral displacement of the pile, the speed of pile movement and the flow of transmitted energy decreased for the piles surrounded by rubber when placed at the top of the pile, while no effect appeared from the presence of rubber when placed around the pile in the middle part and the bottom of the pile. In addition, the impact of the rubber increases as the diameter of the rubber surrounding the pile increases.