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EFFECT OF EARTHQUAKES ON ANCHORED SHEET PILE WALL USING FINITE ELEMENT METHOD

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

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Chapter One

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INTRODUCTION

1.1 General

In essence, sheet pile walls are a part of the subsurface buildings and the transportation network. Geotechnical engineers are very concerned about their subject, especially in nations that are prone to earthquakes **(Singh, A. P. 2023)**.

A method based on the frictional invariance of bulk granular mass was improved by Rankine (1857), who created straightforward equations for the coefficients of active and passive forces on retaining structures. Coulomb (1776) introduced the concept of "critical slip surface" and classified soil strength into cohesive and frictional components. These theories provide the foundation for many analyses of static and dynamic Earth loads on retaining structures because to their clarity and simplicity, which have made them a staple analysis tool in engineering practice (**Basha, A. 2019)**.

Steel, reinforced concrete, or wood are all acceptable materials for sheet piles. Steel sheet trusses are the most popular type used in walls because they have several advantages over other materials, such as being resistant to high as represented in figure (1.1).

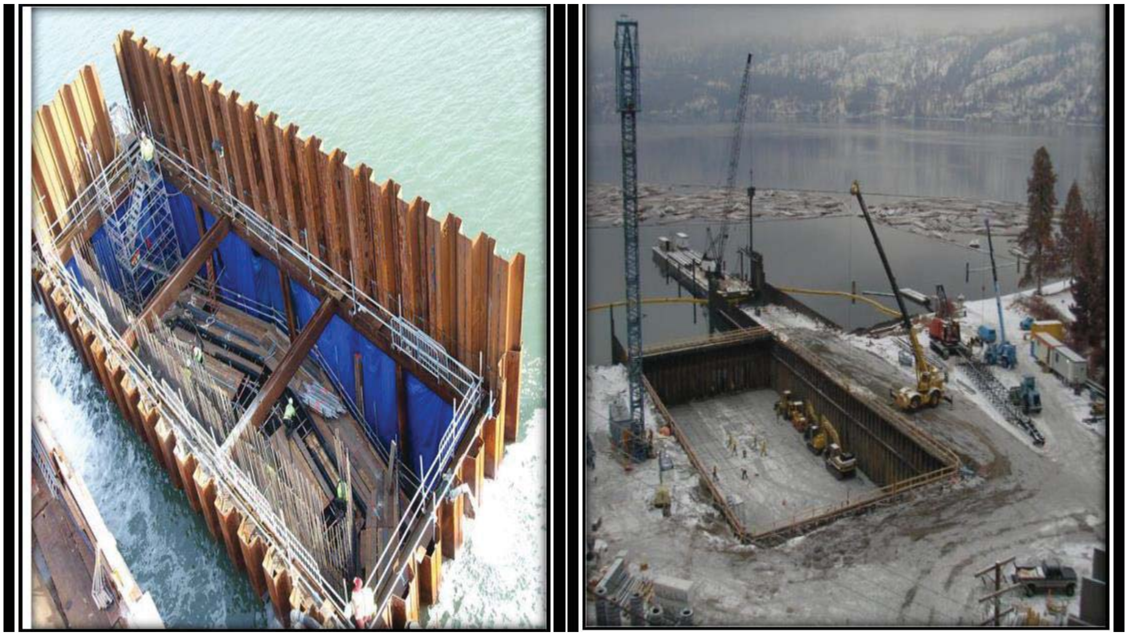

Figure (1.1): Sheet piling wall (design buildings, 2017).

According to the manner of construction, the sheet piles could been divided into two categories: those that were first driven into the ground and then backfilled, and those that are first driven into the ground and then scoop up the earth behind the mound. In either scenario, the soil that is backfilled behind the sheet pile wall is typically granular, and the soil that lies below the dredge line might be either sandy or clayey **(Bowles,1996)**.

Walls made of sheet piles can either be cantilevered or anchored. The function of the wall, the qualities of the foundation soil, and the wall's closeness to existing structures all influence the type of wall that is chosen. Assembled from numerous structural components, such as the retaining wall, tie rods, and anchors, which interact with one another and the earth

Around them, stabilized anchored steel sheet pile (ASSP) walls are intricate retaining structures **(Potnuru,A, 2020)**.

ASSP walls were build using straightforward computational approaches based on limit equilibrium (LE) methods or least-degree interaction Classical analytical methods are still crucial instruments for soil stress analysis and were consequently frequently employed, notwithstanding recent advances in numerical approaches applied to geotechnical engineering. One of the most effective methods for analyzing pile walls is the finite element method (F.E.M. The computer turns out to be a helpful tool in completing the study because executing these analyses requires a lot of complexity and effort. Using numerical finite-difference (FD) and finite-element (FE) methods, the dynamic soil-structure interaction is possible to consider computations and to look for less expensive design options. The choice of representative acceleration time histories, the definition of appropriate boundary conditions, and the selection of an adequate constitutive model for the soil are just a few of the many considerations that must be carefully taken into account when numerically modeling geotechnical systems under dynamic conditions. **(Bilgin Ö 2010).**

These are based on the idea that retaining structures can experience permanent displacements during earthquakes as long as the system as a whole behaves ductile and the damage it causes does not exceed a certain acceptable threshold. The penalty is waived based on the performance standard that is require **(Caputo 2021).**

1.2 The Problem Statement of Study

In Iraq, during the years 2017 and 2018, seismic activities with varying intensity were recorded. More than seventy earthquakes were hit Iraq. Based on the Richter scale, the earthquakes value ranged between 4.0 and 7.3 with depths about from 6.21 to 42.32 km as shown in Figure (1.2). It can be seen from this figure, on November 12, 2017, a big earthquake happened near the border of Iran-Iraq with a value of 7.3 on the Richter scale **(Al-Taie, A.J., &Albusoda,B.S.2019).**

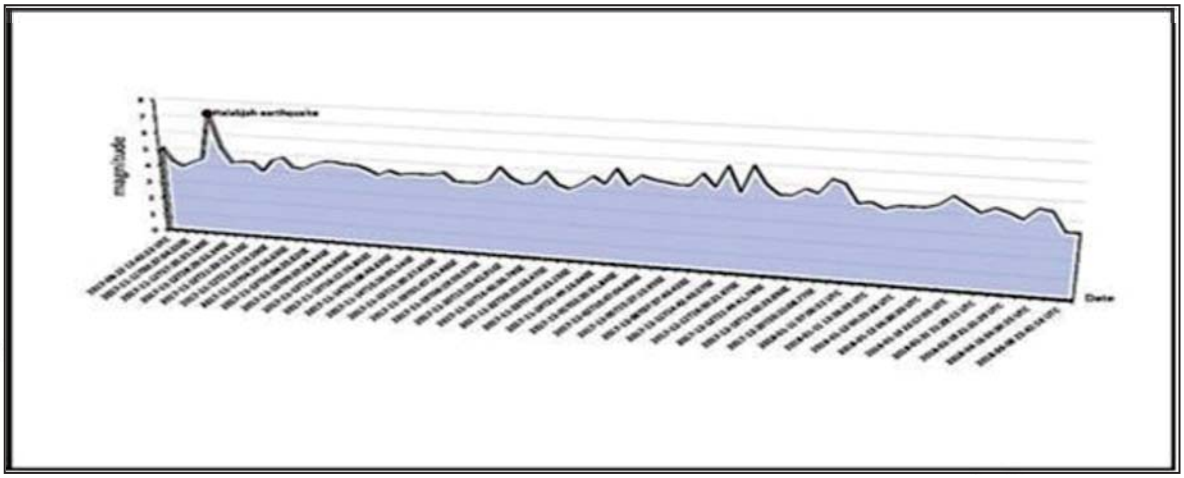

Figure (1.2): Magnitude of earthquakes for the last two months, 2017 and until June in Iraq, 2018 Al-Taie, A. J., & Albusoda, B. S. (2019).

A thorough understanding of ASSP behavior is required in order to prevent damages from occurring as a result of sheet piles that were built in soils that are susceptible to earthquake-induced vibration in seismically active areas and because the thickness of the sheet pile walls is typically thin normally do not exceed 15 mm relative to its section design and located within the soft ground area.

In this work, a variety of case studies and several seismic analysis methods for sheet pile walls are reviewed. This study provides an overview of the seismic effects on the anchored sheet piles and the factors influencing earthquake-related damage to anchored sheet piles. F.E.M has become a popular tool that can simulate the anchored sheet pile walls and the effect of earthquake simulation to predict the strength of deformations and the distribution of stresses.

1.3 The Aims of the Study

The importance of studying the seismic behavior of sheet pile walls and the fact that the residual deformation caused by cyclic motions brought on by an earthquake and the inertial force of a structure have a significant impact on the deformation of walls. Therefor, the aims of this study is oriented in detecting with the following:

1. Estimate the various that happen to the soil body and the anchored sheet pile walls in terms of stresses, lateral displacements and settlement.
2. Calculation zones of failure in soil.
3. Locating zones of safety.
4. The intensity of the proposed earthquake is varied, and the effects were monitored.

1.4 Methodology

1. Collect data from soil reports in Iraq and much preferable in (Diyala).
2. Using the PLAXIS program (Version 20) to calculate the in-situ soil stress, strains, and displacement.

3. A proposed anchored sheet piles with four models that used in this study (α=0, α=15, α=25 and α=30) which are selected according to the last studies about ASSP were constructed in specified dimensions and depth. Lateral displacements, settlement and stresses were calculated in the body of soil around the anchored sheet piles and a little far away and calculate the frequency and velocity for the sheet pile.

4. A Kalamata and Kocaeli earthquakes are simulated in a program and perfected on the anchored sheet pile walls and body of soil.

1.5 Thesis Layout

The layout of this thesis consists of five chapters.

Chapter One: provides a general introduction and information about sheet pile walls in general and then specific in anchored type of sheet pile walls, earthquakes and their effect on anchored sheet piles , and the scope of the study.

Chapter Two: covers a brief review of the available literature of the various sheet pile walls and earthquakes. This chapter also provides a review of previous studies that dealt with the impact of the anchored sheet pile walls and earthquakes on the adjacent soil during sheet piles construction and earthquakes and a review of methods for predicting the behavior of stresses and soil stability.

ChapterThree: presents the numerical modeling methodology for constructing sheet pile walls and earthquakes and the construction model procedures. Also explains field and laboratory investigation data for a limited area.

Chapter Four: includes a presentation and discussion of test results of finite elements.

Chapter Five: presents a summary of the main conclusions and recommendations of future work.

Effect of Earthquakes on Anchored Sheet Pile wall using Finite Element method

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ABSTRACT

Anchored Steel Sheet Pile (ASSP) walls were frequently designed for seismic actions by using pseudo-static methods. Their displacement can be estimated by using the sliding mass approach. Extreme interiors where a deeper understanding of the seismic behavior of these structures is required to identify the key factors affecting forces at the anchor, displacements and settlements which were investigated in this study. In this research project, the seismic behavior of the walls of the ASSP, in dry backfill and penetration in dry clay, where there is no water level in the soil. Two series of dynamic load showed that, in dry conditions, the maximum internal forces were driven by the maximum horizontal acceleration of the earthquake in the backfill. This applying earthquake on the soil and ASSP for different cases of inclination anchors. The finite element method was used to build a mathematical model and it was developed for an ASSP project within the province. For this purpose, one soil investigation file is brought from the Upper AL-Mafraq Intersection Project which is located in Diyala province and two earthquakes consisting of Kalamata and Kocaeli earthquakes are hypothesized and selected based on the latest seismic acceleration in Diyala province.

The model was run in 3D in both clayey soils in two layers and sandy soils in one layer of cases using Mohr -Coulomb model applied by PLAXIS 3D software (Version 20). Four anchor inclination angles were used which were ($\alpha = 0$, $\alpha = 15$, $\alpha = 25$ and $\alpha = 30$) examined to obtain the anchor inclination with respect to the natural ground surface. Three vertical sections were selected to study the effects of the earthquake on the surrounding soil. The first section (X= 19.8 m) is on the left side of the ASSP. The second section is located on the starboard side of the ASSP, while the third section is selected in the middle of the anchor length.

The results of the lateral displacement of the horizontal anchored in the first case(ASSP0) are about (-280 mm) at X =19.8 m, (-310 mm) at X =20.2 m and (-330 mm) at X =30 m, and the settlement ranged for three sections from (120 to 110 mm), because the seismic wave of the movement of two earthquakes, the sheet pile and soil to the left side of sheet pile during the last round of the two earthquakes. The importance of the project lies in reducing the lateral displacement as much as possible to prevent the structure from failing due to the active lateral earth pressure condition of that vertical slope. It is observed that with increasing the slope of the anchor, the forces in the anchors increase and as a result this leads to a decrease in the lateral displacement and the vertical displacement, especially in the cases (ASSP α = 15 and ASSP α = 25) where the lateral displacement changes from (-280 to -260 and -250 mm) at X = 19.8 m, and the vertical displacement changes from (150 to 110 mm) during the three sections, because the incresment the anchoring forces, lowered the lateral and vertical displacement, which becomes better than the horizontal anchor ASSP0. This is because the anchor has become farther away from the failure areas in the soil. However, increasing the inclination of the anchor is not a condition for reducing the lateral and vertical displacement. Where we notice in the case of the anchor inclination at an angle of 30 degrees ASSP30, a large failure occurs in the inclination and gives a higher lateral displacement of about (-330 mm) at X = 19.8 m during two earthquakes because the anchor forces have been reduced and occurred in the soil failure areas.