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Numerical Analysis of Bridge Foundation under Static and Earthquake Loading

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
(Soil Mechanics and Foundation Engineering)

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CHAPTER ONE

INTRODUCTION

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1.1 General

In general, the bridge is a huge structure which is construct over obstacle such as a rivers, or valley, its purpose is to provide paths over this obstacle. Bridge foundation is the part that constructed under the pier and over the underlying soil or rock. The foundation is a component which transfer loads from the super structure to the deep and strong soil stratum. The load transfers by the foundation must not cause soil shear failure or damaging settlement of the superstructure (Bowles, 1997).

1.2 Bridge Foundation

In fact, the pile group of bridge foundation is the most important part because it carries the weight of the bridge (i.e. dead loads) in addition to the traffic loads (i.e. live loads) (Reese et al., 2005). One of the important challenges is design a bridge foundation in a sloping ground. A slope is a surface has an inclined angle with the horizontal surface or ground has a natural incline (Kim et al., 2002).

Safe and economical design of a foundation under different loading conditions is the role of geotechnical engineer. Earthquake loads are the most complicated and complex. Design of earthquake resistant foundation is highly challenging. When one of a large solid piece of hard substance slides against each other the earthquake is occurred and it’s generate flexible waves. The motion of foundation is described as the actual response that the foundation exhibits (Ajom and Bhattacharjee, 2017).

Geotechnical studies deals with the degree of damage for the foundation due to the ground motions from the earthquakes conditions, which causes slope ground settlement, and lateral ground movement. The ground failure appeared as a result of the soil weakness due to vibrations of seismic wave which strike the sloped soil mass and make it slightly unstable. Therefore, to construct a safe structures in a slope ground must prepared a careful and complete study to reduce the failure chance. **Figure (1.1)** shows the ground failure occurred due to an earthquake loading. This type of failure can cause great damages to bridges due to the lateral soil moving (Gega and Bozo, 2017).

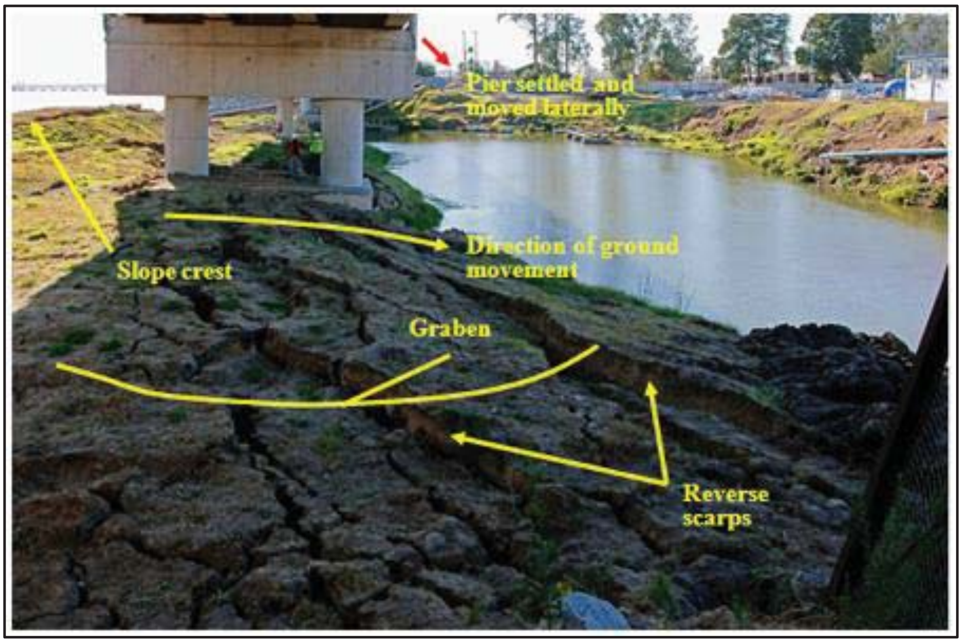

Figure (1.1): Ground failure at bridge foundation (Gega and Bozo, 2017).

On the other side, the Maule earthquake affected on Chilean lifelines, such as the Mataquito River Bridge. As shown in **Figure (1.2)** lateral soil displacements occurred on both banks of the river. The bridge itself was virtually unaffected by the lateral spreading other than some minor abutment wall crushing where the abutment and bridge deck were shoved together either during shaking or as a result of very small lateral movement of the abutment (Gutierrez and Ledezma, 2017).

Figure (1.2): Settlement and lateral deformation of approach embankment at Mataquito Bridge (Gutierrez and Ledezma, 2017).

In addition, settlement of the soil around the interior piers was also observed, see **Figure (1.3)** and appeared to be partly due to lateral spreading of the soil down the slope as well as to weakness of soil that caused settlement under the foundations (Gutierrez and Ledezma, 2017).

Figure (1.3): Soil settlement at interior pier at Mataquito Bridge (Gutierrez and Ledezma, 2017).

In addition to what happened recently, where an earthquake measuring 7.8 degrees on the Richter scale struck southern Turkey and Syria caused many damages to the civil structures, including many bridges, as shown in the **Figure (1.4)**.

Figure (1.4): Collapsed of Kahramanmaraş Bridge in Turkey earthquake 2023 (National Earthquake Information Center).

1.3 Important of the Study

The importance of this study is divided into two parts, the first importance is general and the second is a scientific. The first importance of this study comes from the importance of prediction the expected risks which the bridge foundation is exposed to, and thus is effect on the user's life. In addition to the cost of construction a huge structures as bridge is very high, so, these studies can help to avoiding the waste of public money. The scientific importance of this study is consideration it as a quality study which deals with assessment the bridge foundation performance at the worst conditions. It is expected that the results of this study will have a positive influence in design of similar structures in the future.

1.4 The Problem Statement

From the previous researches which interested in studying the soil-foundation interaction, it was observed that not most effecting variables were taken into account. As example there are a set of studies which deals with analysis of bridge foundation but without calculated the static loads, or without insertion the effect of sloped ground on the civil structures, in addition to many studies neglected the impact of earthquakes on the foundations.

Diyala governorate is located under an active seismic zone and it is necessary to get information about the expected response behavior of structures in this area. Therefore, the idea of this study was formed by connect a set of variables which have direct effect on the bridge foundation.

1.5 The Objectives of Study

This study included the following objectives:

1- Simulation and analysis of bridge foundation, which is located in governorate of Diyala /Iraq using Plaxis 3D software.

2- Assessment for foundation performance at different conditions such as different values of working load, different locations of foundation group such as in flat and sloped ground with different levels of water table.

3- Analysis of bridge foundation under the impact of different earthquake intensities such as Halabjah and Kobe.

1.6 Layout of Thesis

This thesis arranged in five chapters, the topics of these chapters are:

Chapter One: This chapter provides an introduction to Bridge foundations, Important of study, statement of the problem, the objectives of the study, and a description of the thesis organization.

Chapter Two: This chapter includes number of previous studies that related to numerical modeling and analysis of bridge foundation under different loads.

Chapter Three: This chapter illustrates a definition of (PLAXIS V20) software with the main aspects of 3D finite element models. Stress-strain modeling (Mohr-Coulomb, and linear elastic models) with modelling the dynamic loading, boundary conditions, and mesh generation.

Chapter Four: This chapter presents the information of case study with findings and discussion the numerical analysis results.

Chapter Five: Includes the research conclusions and recommendations for future studies.

Numerical Analysis of Bridge Foundation under Static and Earthquake Loading

ABSTRACT

The aim of this study is to investigate the influence of earthquakes loading on the bridge foundation. Al-Shareef Bridge in Diyala province /Iraq which connect the two sides of Baqubah city was selected as a case study. This bridge has 6 spans of 24 m for each, with a total length of 144 m and is supported on reinforced concrete pile groups. The pile group for this case consists of 6 piles, with a dimensions of 1.0 m diameter and 20 m a length of pile with 2x3 pattern and the spacing between piles equal to 3m that is equivalent to 3D of the pile. The concrete pile cap is rectangular with length of 8m, width of 4.8 m and thickness is 1.4 m. The soil layers from project data was (Fill, sand with silt, medium stiff to hard clay and Sand).

The finite element programs (Plaxis 3D) used to simulate this issue, Mohr-Coulomb used for soil modelling and linear elastic for foundation modelling. Two cases of the foundation position are selected, the first one is in flat ground (Group 1) and other in sloped ground (Group 2). Both cases carried simultaneously the earthquake and static axial loads. In this case, different value of Peak Ground Acceleration (PGA) for two types of earthquakes (Halabjah and Kobe), with applied different value of axial loads starts from zero to maximum working loads. In this simulation the dry and saturated soil cases are taken into consideration.

The first step, taking into account only the application of static load, when the axial load increased, the value of settlement (Uz) also increased and reached to 43 mm for (group1) and 45 mm for (group 2) in saturated condition. From these results, it was found that the model of foundation

does not fail when subjected to maximum static loads for both groups. The settlement for Group1 increased about 18% and 71% for both groups under Halabjah earthquake. While, the settlement increase about 71% and 82% for Kobe earthquake. All results of settlement in earthquake case compared with settlement in static case.