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NUMERICAL ANALYSIS OF SEISMIC PERFORMANCE FOR EARTH DAM

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

By

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بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

قَالُوا۟ سُبْحَٰنَكَ

لَا عِلْمَ لَنَآ إِلَّا مَا عَلَّمْتَنَآ ۖ

إِنَّكَ أَنتَ ٱلْعَلِيمُ ٱلْحَكِيمُ

صدق الله العظيم

سورة البقرة

(الاية 32)

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I certify that this thesis entitled " **NUMERICAL ANALYSES OF SIESMIC PERFORMANCE FOR EARTH DAM**" was prepared by "**Marwan Gazzay Deraa**" under my supervision in the University of Diyala in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering.

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I certify that the thesis entitled (**NUMERICAL ANALYSES OF SIESMIC PERFORMANCE FOR EARTH DAM**) presented by **(Marwan Gazzay Deraa)** has been evaluated scientifically, therefore, it is suitable for debate by examining committee.

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Dedication

To …

God, The greatest truth in my life.

My father, the inspirer of my life.

My mother, the sight of my eyes.

My wife, who supported me.

Our honorable teachers who taught and rewarded us their knowledge.

Everyone, who wishes me success in my life,

I dedicate this humble work.

Marwan

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"In the name of Allah, the most beneficent, the most merciful"

First praise be to "Allah" who gave me the strength and health to work and enable me to finish this work.

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Marwan Gazzay Deraa

NUMERICAL ANALYSES OF SIESMIC PERFORMANCE FOR EARTH DAM

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Abstract

Many of earth dams are located within active seismic zones which dictates many efforts to be applied to analyze the seismic behavior of these structures since seismic loads may cause a serious damage to the earth dams like excessive settlement, instability and internal cracking. In order to develop the knowledge about the seismic stability behavior of earth dams, numerical modeling is done throughout this study to a selected case study using the two dimensional finite element method.

The research program of this study includes selecting four representative sections in Mindali earth dam which are located within an active seismic area for studying the influence of applying seismic load in term of earthquake to the stability response using the Geo studio software. The excited earthquake during this study is San Francisco which is used by scaled peak ground acceleration of 0.15 g, 0.2 g, 0.25 g and 0.3 g respectively while the scaled duration periods are 10, 15, 20 and 25 seconds respectively. In addition, four slip surfaces were selected to calculate the safety factor during each time step of analyses which are slope failure up stream, foundation failure up stream, slope failure down stream and foundation failure down stream respectively. The maximum loss in factor of safety has been proposed in this study to characterize the seismic stability behavior of an earth dam since the minimum loss in factor

of safety appears at the same time step within certain defined earthquake duration.

The analyses results showed that a huge increase may be appeared within factor of safety fluctuation profiles during a certain earthquake duration due to the energy release mechanism. The levels of the maximum loss in factor of safety are ranged between (75 to 88) % for slope failure up stream, (56 to 88) % for foundation failure up stream, (34 to 67) % for slope failure down stream and (32 to 63) % for foundation failure down stream.

In addition, a uniform relation has been recognized to the variation of safety loss due to increasing the peak ground acceleration while this variation is not obvious clearly due to the scaled duration. Moreover, a preliminary dependency study showed that correlation of such variation is generally positive but low to moderate in all sections for the proposed slip surfaces.

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Item	Description
q	The specific discharge
k	The hydraulic conductivity
i	The gradient of total hydraulic head
H	Total head
k_x	Hydraulic conductivity in the x-direction
k_y	Hydraulic conductivity in the y-direction
Q	Applied boundary flux
Θ	Volumetric water content
t	Time
σ	The total stress
u_a	The pore-air pressure
u_w	The pore-water pressure
m_w	The slope of the storage curve
γ_w	The unit weight of water
y	The elevation
τ	The thickness of an element.
$[B]$	The gradient matrix.
$[C]$	The element hydraulic conductivity matrix
$\{H\}$	The vector of nodal heads
$<N>$	The vector of interpolating function
λ	The storage for the transient seepage
A	A designation for summation over the area of an element
L	A designation for summation over the edge of an element
S	Shear strength
c'	Effective cohesion intercept

LIST OF ABRIVIATIONS

φ'	Effective angle of internal friction
W	The total weight of a slice of width b and height h
N	The total normal force on the base of the slice
S_m	The shear force mobilized on the base of each slice
E	The horizontal inter slice normal forces. Subscripts L and R designate the left and right sides of the slice, respectively.
X	The vertical inter slice shear forces. Subscripts L and R define the left and right sides of the slice, respectively.
k_W	The horizontal seismic load applied through the centroid of each slice.
θ_w	The volumetric water content
θ_s	The saturated volumetric water content
θ_r	The residual volumetric water content which is 10% times the saturated volumetric water content is SLOP/W.
υ	Poisson's ratio

CHAPTER ONE
INTRODUCTION

1.1 General

Actually, dam is a unique project which are usually used to impound and / or divert water for beneficial uses like irrigation, originally, this type of projects can be classified according to many aspects like hydraulic attributes, function nature and materials of construction.

Moreover, zoned earth fill dams are generally preferred for the possibility of using a large spectrum of available materials in the borrow areas. This type may usually carry seismic load in many cases which dictates as a consequence that the dam designers should take earthquakes in their considerations to insure withstanding the future shocks and the consequent possible damage which may be serious in nature. More precisely, such designers have an aim to estimate the general behavior of earth dams under earthquakes as well as the exerted ground motion and the resulted forces (Ayar, 1985).

On the other hand, many of the reported earth dams failure cases are ascribed in the past to the presence of unexpected impacts of earthquakes which can appear in term of settlement, instability and even internal cracking. Consequently, studying the matter of earth dams stability under seismic load is an important issue and represents a common goal for many scientific research programs. The current study tries to investigate the stability seismic behavior of earth dams through numerical modeling.

1.2 Zoned Earth Dams

In fact, earth dams are such types of dams which built usually of compacted soil and / or rock fractions. These dams are designed as gravity dams, more massive in nature than other types and as a consequence require larger amounts of row materials (Coduto, 1999).

On the other hand, earthen dams utilizes natural materials with minimum processing in most cases by using primeval instrumentations.

As a matter of fact, the earth dam section may be in different configurations, such section may consist of only one homogenous material if the required total height of dam is relatively low as shown in Figure (1.1a). Additionally, that section may include typical zoning by using certain types of materials for the purpose of controlling seepage.

When borrow area does not contain enough quantities of impervious materials, impervious central cores can be constructed within earth dam as shown in Figures (1.1b and c). More insightfully, the vertical core configuration is preferred over the inclined core ones for the ability to prevent leakage, good stability under seismic load and the flexibility in performing remedial procedures regarding seepage control. On the other hand, inclined upstream cores have an excellency to allow downstream portion to be constructed first which in turn have led to reduce the possibility of fracturing (Nasif, 2008).

When the case of previous foundation is exist as shown in Figures (1.1d and f), seepage control is a governing issue due to the possible presence of excessive uplift pressure and piping within dam foundation area. However, probable remediation's her are cutoffs, downstream seepage berms, relief wells and toe drains.

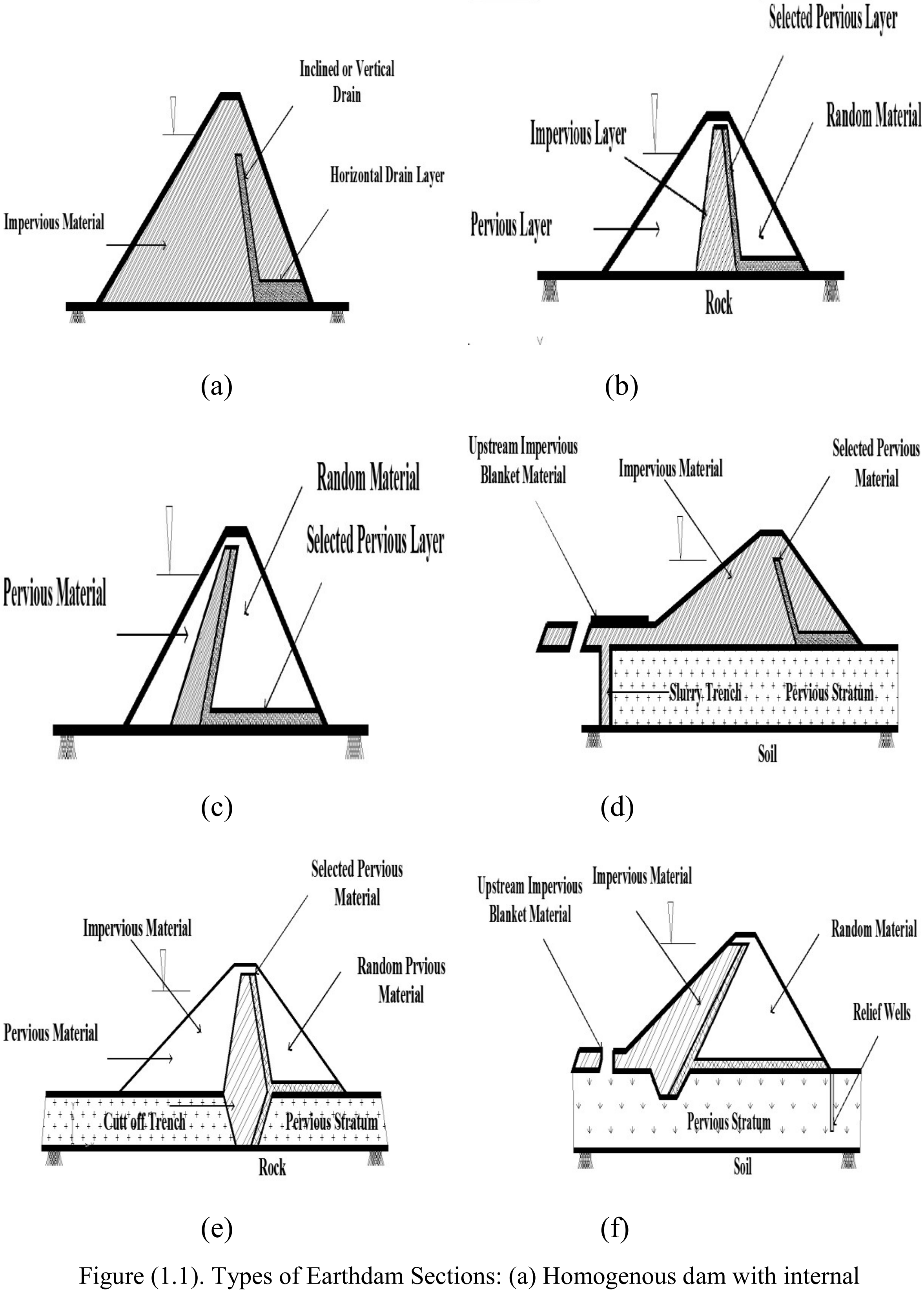

Figure (1.1). Types of Earthdam Sections: (a) Homogenous dam with internal drainage. (b) Central core dam on impervious foundation. (c) Inclined core dam on impervious foundation. (d) Homogenous dam with internal drainage on pervious foundation.(e) Central core dam on pervious foundation. (f) Dam with upstream Impervious material (after Mcmahon, 2004)

1.3 Representative Case Study

Mandali dam is used as a case study throughout the present study to investigate the stability of earth dam under seismic load. This dam is classified as zoned earth dam with the presence of central clay core. In addition, it is known that this dam is located in active seismic area (Mandali Dam Design Report), hence, studying the matter of stability under seismic load is very important and justified. The full details will be presented ~~separately~~ in chapter 4.

1.4 Importance of the Study

Earthquakes is considered the strongest possible force that can be affect in term of severity of damage that can destruct properties, injure and cause death of live to the human civilizations.

Furthermore, earth dams are made usually by natural earth materials which makes it behave flexible unlike concrete dams wherein illustrate a behavior near rigid structure. In this way, such earthquake loading may be considered as a serious source of hazard to earth dam structure and the issue of its stability should be studied in intensive manner in to prevent possible disasters since such structures may provide irrigation water and it may have secondary damage to the nearby habitation. So, a field case study need to be taken to show the adverse effects of earthquake loading.

1.5 Aim and Objectives

The basic aim of this study is to investigate the impact of an earthquake to the stability of earth dam. The following objectives are established to achieve such aim:

- Simulate the selected case study (Mandali dam) which is located in active seismic area.
- Study the influence of earthquake duration and peak ground

acceleration to the slope stability at different locations within earth dam body.

1.6 Thesis Layout

The general layout of this study consists of five chapters as explained below:

Chapter one: Presents a brief introduction of the problem and earth dams demonstrating the, aim and objectives of the study.

Chapter Two: Presents a background depending on the literature re view of the recent studies.

Chapter Three: Presents an overview to the seismic waves and earthquake definition as well as the expected impacts of these issues to the earth dams. This chapter includes also outlines for the earthquake presence and distribution within Iraq.

Chapter Four: Lists the common equations that govern the dynamic analysis. The computer program used in this study was also described briefly showing some of its common capabilities.

Chapter Five: The impact of earthquake to the earth dams with respect to stability is analyzed and the analyses results were viewed and discussed using the case study presented throughout this scientific program.

Chapter Six: Contains the conclusions and recommendations based on analyses results taken from the previous chapters.