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Stability of Small Hydraulic Structures Under Seismic Load

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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بسم الله الرحمن الرحيم

فَبَدَأَ بِأَوْعِيَتِهِمْ قَبْلَ وِعَاءِ أَخِيهِ ثُمَّ اسْتَخْرَجَهَا مِنْ
وِعَاءِ أَخِيهِ كَذَلِكَ كِدْنَا لِيُوسُفَ مَا كَانَ لِيَأْخُذَ
أَخَاهُ فِي دِينِ الْمَلِكِ إِلَّا أَنْ يَشَاءَ اللَّهُ نَرْفَعُ دَرَجَٰتٍ مَنْ
نَشَاءُ وَفَوْقَ كُلِّ ذِى عِلْمٍ عَلِيمٌ

صدق الله العظيم

القران الكريم سورة يوسف، الاية (٧٦)

CERTIFICATION OF THE SUPERVISOR

I certify that this thesis entitled " **Stability of Small Hydraulic Structures Under Seismic Load** " was prepared by **"Abdullah Saleh Naseef"** 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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(Supervisor)

Date: / /2021

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We certify that we have read the thesis entitled " **Stability of Small Hydraulic Structures Under Seismic Load** " and we have examined the student **(Abdullah Saleh Naseef)** in its content and what is related with it, and in our opinion it is adequate as a thesis for the Degree of Master of Science in Civil Engineering.

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DEDICATION

I dedicate this research to;

My Dear Father;
His words of inspiration and encouragement in pursuit of excellence.

***My Affectionate Mother*;**
Whose prayers and love took me to zenith of glory and transform my dreams into reality.

My Brothers and Sister;
Who have always encouraged and supported me for further study.

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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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Abdullah Saleh Naseef

Abstract

The small hydraulic structures may be constructed in active seismic areas, where ground shaking can impose considerable earth pressures on them. The safety of these structures should be investigated quite critically by logical and precise methods. In order to design earthquake - resistant dams, it is essential to have accurate and reliable analysis procedures to predict dam response.

Rawanduz dam (subjected to EL-Centro, Ali AL-Gharbi, Taft earthquakes) is investigated as a typical case of study. Analyzing and evaluating the stability of the concrete dam and assessing the impact of key parameters which affect the dynamic behavior of the concrete dam, are the main objectives of this study.

A 2-D Finite Element model is employed using ANSYS program to simulate dam response. The dam body is assumed to be homogeneous, isotropic, and elastic properties for mass material. The soil is assumed to be flexible and analyzed as a nonlinear material. The hydrodynamic pressure was modeled according to added mass theory, which states that the water pressure exerts on the dam during an earthquake is the same as if a certain body of water moves back and forth with the dam while the remainder of the reservoir was left inactive.

Seismic dam responses are expressed in terms of deformations, stresses and the time history of horizontal displacement.

The researcher determined the exit gradient and its value was equal to (0.1), which is less than the safe value of the exit gradient (0.6).

The dynamic stress state analyses show that the stability criteria are met for the concrete of the dam because the maximum compression stress (0.24295 Mpa) does not exceed the allowable compressive strength of the concrete which is

25MPa and the maximum value of the tensile stress (0.40709 Mpa) was less than the allowable tension strength of the concrete which is 2.74MPa.

The parametric study included key parameters which affect the dynamic behavior of concrete dam such as the influence of different water level, the effect of seismic frequency and effect of foundation stiffness. The researcher finds these parameters have a significant effect on dam seismic response.

When the foundation stiffness increases, the dam deformation decreases because decreases in the settlement, and this occurs due to the inverse relationship between the modules of elasticity for soil and the settlement. Also, the natural frequency for the concrete dam is increasing with the increasing of foundation stiffens.

When studying the effect of water height, the researcher notes that in all cases of the water height change, there are tensile stresses at the heel. This tensile stresses may be leaded to cracks between the dam body at heel and the rock foundation. Ground motion variation affects dam seismic response, although the different ground motions have the same peak acceleration. This means that any change in dynamic characteristics leads to a significant difference in structure behavior when subjected to different ground motions.

Results confirm the dominant effect of foundation stiffness on dam response over other parameters.

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List of Abbreviation

Item	**Description**
F.O.O	Factor against overturning
ΣV	the total vertical force
B	base width of the dam
μ	coefficient of friction between the dam base and foundation
ΣH	total external horizontal forces
q	average shear strength of the joint
$\mathbf{k_x}$, $\mathbf{k_y}$, $\mathbf{k_z}$	permeability coefficient at x,y,z direction
u_s	Reservoir capacity
T	the temperature
p	the mass density
c	specific thermal coefficient
P	maximum hydrodynamic pressures at height y
h	reservoir depth
ρ	unit density of water
$\mathbf{k_h}$	seismic acceleration coefficients in the horizontal direction
g	acceleration of gravity (9.8 m/s^2)
U	system of relative displacements
$\dot{U}$	velocity
$\ddot{U}$	acceleration vectors with respect to the base, respectively

I	Influence vector
ü g	sollicitation direction
M	System mass
C	damping
K	stiffness matrix
***ü* g**	Horizontal component of ground acceleration.
A	section of the bar
C	wave velocity

CHAPTER ONE
INTRODUCTION

1.1 General

Throughout history, water has been considered to be a critical natural resource on which mankind's very survival has depended. In order to ensure water availability for domestic and agricultural purposes and also for protection against floods, retaining structures have been built for thousands of years. As science and technology have advanced, larger and more complex infrastructures have been built to support ever-increasing human activities in the domestic, agricultural, and industrial sectors **(Tortajada, 2015)**.

Most suitable site must be chosen for construction; ideally it must be a small valley or a narrow gorge with sufficient catchment area available behind so that the amount of water can be simply stored in the reservoir created upstream. Concrete dams are very important structures, regarding to requirements for continuous service during their life time, and catastrophic effects in cases of dam failure. Therefore, the safety of these structures should be investigated quite critically by logical and precise methods **(Chen and Chen, 2015)**.

The Reservoir-dam-foundation interaction is one of the main factors that affects dam behavior during earthquake excitations. The analysis of reservoir-dam-foundation coupled system is much more complicated than that of the dam alone because of the difference between the characteristics of reservoir, foundation and concrete dams. In order to design earthquake resistant dams and evaluate the safety of existing dams that will be exposed to future earthquakes, it is essential to have accurate and reliable analysis procedures to predict the stresses and deformations in dams subjected to ground motion.

1.2 Research Justification

The hydraulic structure may be constructed in active seismic areas, where ground shaking can impose considerable earth pressures on them.
Failures of the small hydraulic structures under static and earthquake loads can cause significant economic loss. Therefore, it is important to investigate the stability of the hydraulic structures and ensure their safety to understand their responses to such loads.

1.3 Research Scope

It's essential to study the impact of earthquakes on the stability of small hydraulic structures in Iraq, due to the several earthquakes which have been exposed in many Iraqi regions. These earthquakes can cause severe damages to the hydraulic small structures existing at a huge number were build in Iraq.
Rawanduz Dam in the Governorate of Erbil has been selected in this study because of completing data of this site.

1.4 Objectives of the Study

1. Analyze and evaluate the stability of the small hydraulic structure (Rawanduz dam as a case study) under the influence of seismic loading.
2. Assess the impact of key parameters which affect the dynamic behavior of concrete gravity.

These parameters can be summarized as follows:

a.influence of different water levels on the dam.

b.effect of seismic frequency on the dam.

c.effect of foundation stiffness.

1.5 Assumption and Limitations of the Study

The study is subjected to the following assumptions and limitations:

1. The dam body is assumed to be homogeneous, isotropic, and elastic properties for mass material.
2. The foundation is assumed to be flexible and analyzed as a nonlinear material.
3. The hydrodynamic pressure was modeled as an added mass according to Westergaard 1993 theory, which states that the pressure of the water exerts on the dam during an earthquake is the same as if a certain body of water moves back and forth with the dam while the remainder of the reservoir is left inactive.

1.6 Organization of the Thesis

Chapter 1: Introduction

gives an introduction, purpose, and aim of the thesis.

Chapter 2: Literature Review

presents the literature review of the previous work that concerns the scope of the present study.

Chapter 3: Theoretical Approach and Numerical Modeling

presents the governing equations, boundary conditions, Finite Element technique, ANSYS modeling, description of the studied dam.

Chapter 4: Numerical Results and Discussion

discusses the results that demonstrate analyze and evaluate the stability of the Rawanduz dam and the effect of different water levels, ground motion excitation, and foundation stiffness on the dynamic behavior of dam.

Chapter 5: conclusions

introduces the main conclusions drawn from the results.