AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
STRUCTURAL ENGINEERING DEPARTMENT

Seismic analysis For Pure Conical Elevated Tanks Including Fluid Structure Interaction

Thesis
Submitted in Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE
In
CIVIL ENGINEERING (STRUCTURES)

By

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CURRICULUM VITAE

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STATEMENT

This thesis is submitted to Ain Shams University for the degree of M.Sc. in Civil Engineering.

The work included in this thesis was carried out by the author at the Department of Structural Engineering, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

No part of this thesis has been submitted for a degree or a qualification at any other University or Institution.

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ABSTRACT

Liquid-containing tanks are used in water distribution systems and in industries for storing toxic and flammable liquids, also water supply is essential for controlling fires that might happen during earthquakes, which cause a great damage and loss of lives. Therefore, elevated tanks should stay serviceable in the post-earthquake period to ensure water supply is available in earthquake-affected regions and to prevent catastrophic damage if those tanks collapsed. The truncated conical shape tank is used for transferring materials such as water and pesticides to many locations; also it provides easy draining of materials and an easy cleaning manner. Due to inclination of conical tanks` walls, the seismic response of a conical tank is expected to be different from the response of a cylindrical tank. Research studies associated with the dynamic performance of cylindrical tanks are comprehensive.

According to most of current design codes, if the container has a conical shape, an equivalent cylinder tank procedure may be followed, although a limited number of researches have investigated the seismic performance of conical tanks. The first studies on the dynamic response of conical tanks were done by El Damatty et al. (1997). An experimental work was accomplished by Sweedan and El Damatty (2002) to explore the dynamic characteristics of conical vessels. El Damatty and Sweedan (2006) have developed a mechanical model that can be utilized to evaluate the seismic response of conical tanks subjected to horizontal ground excitations.

The main objective of this study is to create a parametric study for conical ground and elevated tanks by using the mechanical analog parameters developed by El Damatty and Sweedan (2006) to study the fluid-structure interaction and seismic response of those tanks through three dimensional finite element models using SAP2000 V15.1.0 software by using response spectrum analysis. Results obtained are then compared with the corresponding values obtained from American Water Works Association (AWWA D100 (2005)) and Egyptian code for loads (ECP 201

– 2012) procedures. The effect of changing geometric features of the tank are investigated such as vertical inclination of vessel`s walls, liquid height to radius at the base of the vessel ratio (hw/Rb), volume of the tank, and height of elevated tanks.

Finally an evaluation was done one the parametric study findings and it was found that the vertical inclination angle of the tank walls of 15^{o} is the angle where the internal forces in the tanks are the minimum, also correction factors are recommended to be used for equivalent cylinder tanks approach of design codes to get a more conservative seismic response.

- **Keywords:** conical tanks; fluid-structure interaction; seismic analysis; seismic response; added mass approach; mechanical analog.

SUMMARY

According to most of current design codes, if the container has a conical shape, an equivalent cylinder tank may be used, although a limited number of studies have investigated seismic response of conical tanks. El Damatty and Sweedan (2006) have developed a mechanical model that can be utilized to evaluate the seismic response of conical tanks subjected to horizontal ground excitations. The main objective of this study is to create a parametric study for conical ground and elevated tanks by using the mechanical analog parameters developed by El Damatty and Sweedan (2006) to study the fluid-structure interaction and seismic response of those tanks through three dimensional finite element models using SAP2000 V15.1.0 by using response spectrum analysis. Results obtained are then compared with the corresponding values obtained from American Water Works Association (AWWA D100 (2005)) and Egyptian code for loads (ECP 201 – 2012) procedures. Finally an evaluation was done on the parametric study findings to reach the vertical inclination angle of the tank walls where the moment below tank walls is the minimum for the same tank volume and liquid height to base radius of the vessel ratio (hw/Rb), also correction factors are recommended to be used for equivalent cylinder tanks approach of design codes to get a more conservative seismic response.

The thesis is divided into seven chapters

Chapter (1) is the introduction to this research; it discusses the scope and the main objectives of the research.

Chapter (2) is a literature review which briefly discusses the past researches of the response and the behavior of liquid containing ground and elevated tanks, the historical disastrous damages of tanks. Seismic isolation systems are also briefly studied. Also, design codes and standards guidelines for design and analysis of tanks are also summarized.