Dynamic Behavior of Base-Isolated Flexible Rectangular Fluid Containers

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Abstract

An analytical method is proposed to determine the dynamic response of 3-D base isolated rectangular fluid containers with four flexible walls, subjected to seismic ground motion. By applying Rayleigh-Ritz method using the vibration modes of flexible plates, fluid-structure interaction effects on the dynamic responses of fluid containers are considered. A mechanical model, which takes into account the deformability of the tank wall, is developed. The maximum seismic loading of the base at the tank and a section immediately above it can be predicted by this model. Accordingly, a 2-D simplified model is proposed to evaluate pressure distribution on the flexible tank wall. The effects of base-isolation on the seismic response of rectangular liquid storage tanks subjected to horizontal seismic ground motion are presented. Results show that seismic base isolation can be an efficient way to reduce dynamic responses such as base shear, base moment and hydrodynamic pressure.

Keywords: Rectangular tank, Fluid-structure interaction, Seismic design, Rayleigh-Ritz method, Base-isolation.

1. INTRODUCTION

Liquid storage tanks are important components of lifeline and industrial facilities. They also play an important role in the rescue work after an earthquake. These structures are used extensively for the storage of a variety of liquid-materials such as oil, liquefied natural gas, chemical fluids and the long-term storage of nuclear spent fuel assemblies, and therefore, a major damage or collapse during an earthquake can have a major impact to the environment. The poor performance of some of these structures in past earthquakes has led engineers and researchers to study this problem, and to improve the behaviors of these structures.

There are some numerical and a few analytical methods available that have been used for dynamic analysis of concrete rectangular liquid storage tanks. Hoskins and Jacobsen [1] published the first report on analytical and experimental observations of rigid rectangular tanks under a simulated horizontal earthquake excitation. Housner [2,3] developed the most commonly used analytical model for estimating the dynamic response of a rigid rectangular tank. This model, with some modifications, has been adopted in most of the current codes and standards.

The 1964 Alaska earthquake caused the first large-scale damage to tanks of then modern design and initiated many investigations into the dynamic characteristics of flexible containers. Several studies were carried out to investigate the dynamic interaction between the deformable wall in the tank and the liquid, and showed that the seismic response of a flexible tank may be substantially greater than that of a similarly rigid tank. A three-degrees-of-freedom (3 DOF) model of the ground-supported cylindrical tank was developed by Haroun [4], the application of which resulted in design charts used to estimate sloshing, impulsive and rigid masses.

For rectangular tanks, Haroun [5] presented a very detailed method of analysis on the typical system of loadings. The hydrodynamic pressures were calculated by a classical potential flow approach. The formula of hydrodynamic pressures only considered the rigid wall condition. This may be due to the fact that rectangular fluid containers are usually made of reinforced or pre-stressed concrete and may be considered quite rigid dynamically. Nevertheless, there are containers of this type for which flexibility must be taken