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Investigation of Soil Structure Interaction and Wall Flexibility Effects on Natural Sloshing Frequency of Vessels

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Abstract

The main purpose of this study is to establish the effects of vessel walls flexibility on its natural sloshing frequency considering soil-structure-fluid interaction theory. Furthermore, two new efficiently relations to find both of wall flexibility and soil-structure interaction effects on natural frequency are developed. Regarding the aim of current study three different conditions of elevated tanks are applied. Fixed base condition with an emphasis on recommendations of international code ACI-350, analytical FSSI regarding equivalent mass spring method, and the numerical direct method regarding theory of finite element are taken into consideration. Results indicate that there is no significant effect of walls flexibility on natural sloshing frequency regarding fixed base assumptions of vessels. On the contrary, significant effects of wall flexibility are achieved considering SSI theory. Results of international code ACI-350 show that, the international codes assumptions have imprecise estimations of natural sloshing frequency in the range of hard to very soft soil categories. On the other hand, it is observed that the wall flexibility has a more highlighted effect on natural frequency in soft soils rather than soil-structure interaction. The significance of wall flexibility effect on natural frequency is more than that of SSI considering soil softening.

Keywords: Natural Sloshing Frequency; Finite Element; Flexibility; Vessel; Soil-Structure Interaction.

1. Introduction

Regarding recent reports, there are many vessels that were collapsed or experienced remarkable damage during earthquakes that have occurred all around the world. A large proportion of such loss have been observed during recent earthquakes, which have occurred from reasons like unsuitable design of construction of tanks on loose soil and ignoring the effects of the soil structure interaction (SSI) [1, 2]. Because of a complete recognition of hydrodynamic liquid effects on vessels of elevated tanks, lots of researchers recommended inquiries to fluid-structure interaction (FSI) method [3-5]. The most accurate method for liquid storage /elevated tanks modelling is Fluid-Structure-Soil Interaction (FSSI) [6]. To simplify the issue all international codes and regular relations assume that walls of vessels are rigid and there is no deformation in the body of vessel considering fluid fluctuation.

As a good method to find the soil effects on superstructures, pervious researcher recommended to use the analytical equivalent mass spring method [7, 8]. The soil stiffness matrix of the surrounding soil is represented by a 2 × 2 matrix where K_x, K_θ and $K_{x\theta}$ are the sway, rocking and sway-rocking coupling terms of the corresponding static stiffness matrix, respectively [7, 9].

$$\begin{bmatrix} K_x & K_{x\theta} \\ K_{x\theta} & K_\theta \end{bmatrix}$$

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