Experimental investigation of sloshing in a rectangular tank using a numerical simulation

Mohammad Reza Shekari

1- Assistant professor, Civil Engineering Department, Yasoug University, Iran.

m.shekari@yu.ac.ir

Abstract

Pressure variations and 3D effects on liquid sloshing loads in a moving partially filled rectangular tank have been performed numerically. Recently, extensive advances have been made in the development of numerical techniques for investigating the effects of liquid sloshing on large structures. However, there is a lack of experimental data that may be used for validating the analytical and numerical solutions acquired. This paper presents a numerical algorithm which is achieved through the use of finite shell elements for the structure and internal boundary elements for the liquid region. Several configurations of both baffled and unbaffled tanks are considered to show the slosh loads in the cases investigated. It is observed that baffles significantly reduce the fluid motion and accordingly the pressure response.

Keywords: sloshing loads; Pressures variations; Boundary elements; Finite elements

1. INTRODUCTION

Fluid motion in liquid storage tanks may cause large structural pressures if the period of tank motion is close to the natural period of fluid inside the tank, which called liquid sloshing. The amplitude of this phenomenon, ordinarily, depends on the amplitude and period of the tank motion, tank wall geometry and liquid-fill depth. Depending on the type of earthquake, i.e. impulsive, sinusoidal, periodic and random, the dynamic behavior of a free liquid surface extensively varies. Failure of nuclear power plants, petroleum tanks, etc. creates an important research area in seismic analysis of liquid storage tanks [1,2].

The liquid forces and movements generated by sloshing in case that the external excited frequency is close to the fundamental sloshing frequency may result in destruction of the structures. The usual way to treat the worrying problem is to vary this instability frequency. This may be reached by covering the free surface with a flexible structure member, such as a membrane or a thin baffle plate. These make the natural sloshing frequencies diverge from the excited frequency and reduce the sloshing masses. The study of coupled frequencies resulting from fluid-structure interaction is very significant. There are many researches to solve the fluid-structure interaction problems of the structural elements on liquid free surface and in liquid domain. There are some papers on partially liquid filled or empty containers, in which the different seismic analysis techniques are compared [3–6]. Evans and McIver (1987) explored the fluid frequencies in rectangular container including a vertical baffle and developed a technique on the basis of matching the appropriate eigenfunction expansions on either side of the baffle and solution of the resulting integral equation for the horizontal fluid above or below the baffle [7]. Afterwards, Watson and Evans (1991) expanded this technique for a number of similar problems [8]. Gavrilyuk et al. (2006) suggested fundamental solutions of the linearised problem on fluid sloshing in a vertical cylindrical tank having a thin rigid-ring horizontal baffle [9]. Sames et al. (2002) investigated sloshing in a rectangular tank with a baffle and in a cylindrical tank [10]. The main purpose of this study is to develop a numerical technique accounting for the effects of large tank motions, liquid depths, and baffle arrangements on the basis of experimental data.

2. FLUID DOMAIN FORMULATION

In the present investigation, it is assumed that the fluid is ideal, i.e., inviscid and incompressible, and its motion is irrotational. Hence, the governing equation of liquid motion is represented by the Laplace equation,

$$\nabla^2\varphi = 0 \tag{1}$$