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Study of hydrodynamic pressure on wall of tank

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Abstract

Liquid-containing tanks are used to store variety of liquids. This work considers the theoretical background of seismic response of liquid storage ground-supported tanks, i.e. hydrodynamic effect of fluid on solid wall of rectangular endlessly long tank fixed to rigid foundation. For numerical analysis of hydrodynamic pressure was used Finite Element Method (FEM) and as loading was considered as horizontal ground motion the accelerogram Loma Prieta was considered.

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Keywords: fluid, tanks, pressure

1. Introduction

Ground-supported circular containers are important structures in industries, which are used to store a variety of liquids, e.g. water for drinking and fire fighting, liquefied natural gas, petroleum, chemical, different chemical wastes. It is know that, some of the fluid tanks are damaged in many earthquakes. Damage or collapse of these containers causes some unwanted events such as shortage of drinking and utilizing water, uncontrolled fires and spillage of dangerous fluids. Seismic damage of liquid storage containers during recent earthquakes demonstrates the need a reliable technique to assess their seismic safety [20-25].

Seismic design of liquid storage tanks has been adopted in [10-15, 19]. When a tank containing liquid vibrates, the liquid exerts impulsive and convective hydrodynamic pressure on the tank wall and the tank base, in addition to the hydrostatic pressure. The dynamic analysis of a liquid filled tank may be carried out using the concept of generalized single degree of freedom (SDOF) systems representing the impulsive and convective modes of vibration of the tank - liquid system.

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The finite element method is well established for the complex engineering analysis of problems involving structures, fluids and interaction between fluid and solid. The fluid structure interaction problem is presented in various engineering activities, as civil buildings, mechanical devices, biomechanics etc.

For the fluid-structure interaction analysis, there are possible three different finite element approaches to represent fluid motion - Eulerian, Lagrangian and mixed methods. In the Eulerian approach, velocity potential (or pressure) is used to describe the behavior of the fluid, whereas the displacement field is used in the Lagrangian approach. In the mixed approaches, both the pressure and displacement fields are included in the element formulation [1-9, 16-18].

2. Numerical Experiment, results and conclusion

In the present study, a ground supported rectangular reinforced concrete endlessly long channel as shown in Fig. 1, is considered. The channel with inner width *L* of 6.0 m and total height of walls 3.5 m is fully anchored to concrete foundation. The tank is filled to a height *H* of 3.0 m. The wall of the container has the uniform thickness 0.35 cm and modulus of elasticity of tank material is $37\cdot10^6$ GPa. We consider, as the excitation loading, the horizontal earthquake loading - the accelerogram of the earthquake in Loma Prieta, California (18.10.1989), we use in analysis just seismic excitation in *y* - direction. The endlessly long open top shipping channel container is filled with water (H_2O) of density ρ_w = 1 000 kg/m^3 bulk modulus $B = 2.1\cdot10^9$ N/m^2.

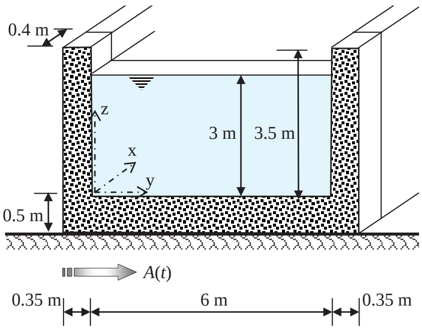

Fig. 1. Endlessly long tank geometry.

Dynamic time-history response of concrete rectangular fluid filled chipping channel was performed by application of Finite Element Method (FEM) utilizing software ADINA. For the problem was used Arbitrary-Lagrangian-Eulerian (ALE) formulation and for simulation of the interaction between the structure and the fluid at the common boundary were used two way Fluid-Structure Interaction (FSI) techniques. The solid walls and base of the shipping channel was modeled by using 3D SOLID finite element and the fluid filling of the shipping channel by using 3D FLUID finite elements. The input time dependent horizontal displacement measured during the earthquake Loma Prieta in California was considered as the excitation for numerical simulation Fig. 2.

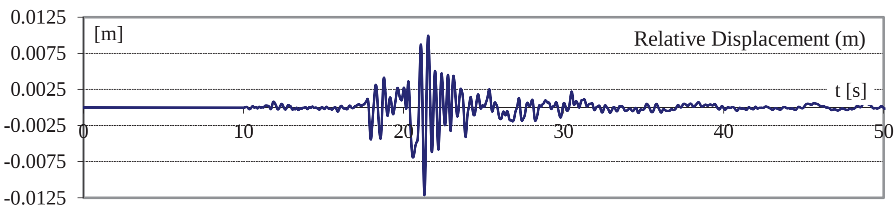

Fig. 2. Input time dependent horizontal displacement measured during of earthquake Loma Prieta.

Bigger value of fluid pressure was acting on the right edge of fluid region. Fig. 3 shows the resulting time dependent response of the fluid pressure in downright edge of fluid region.