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Numerical Experiment of Fluid - Structure - Soil Interaction

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Abstract

Ground-supported circular tanks are critical and strategic structures. There structures are used to store a variety of liquids. This paper provides numerical model on seismic response of fluid - structure - soil interaction. Numerical model on seismic response of fluid - structure -soil interaction of cylindrical tank was obtained by using of Finite Element Method (FEM). They can also be fluids, which in case of damage to the tank, can contaminate the ground. Damage or collapse these containers may also be due to the influence of surrounding aggressive environments or an earthquake. The article also will be described impact aggressive environment in terms of standards and its impact on the quality of the concrete tank.

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Keywords: fluid; tanks; seismic response; soil interaction; environment;

1. Introduction

Ground-supported circular tanks are essential structures in industries and used to store a variety of liquids, e.g. water for drinking and fire fighting, chemicals, petroleum and liquefied natural gas. 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. In the recent decades, the importance of fluid-structure-soil interaction (FSI) of dynamic response of key structures such as silos, storage tanks and also other types of structures have been presented in various studies [9,11-12,14-18,23].

The seismic analysis and design of liquid storage tanks is, due to the high complexity of the problem, in fact, really complicated task. Number of particular problems should be taken into account, for example: dynamic interaction

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between contained fluid and tank, sloshing motion of the contained fluid; and dynamic interaction between tank and sub-soil i.e. soil-structure interaction (SSI). Those belong to wide range of so called fluid structure interactions. The knowledge of fluid effects acting onto walls and the bottom of containers during an earthquake plays essential role in reliable and durable design of earthquake resistance structure/facility - tanks [1-8,13,19-21].

2. Numerical Experiment of Fluid/Structure Interactions (FSI)

In the present study, a ground supported cylindrical storage tank, without a fixed or floating roof, is considered. Tank inner diameter is D = 14 m, height is H_w = 7.25 m and the wall of the container has the uniform thickness 0.25 m. The base slab of the tanks is 0.4 m. Young's modulus and the weight of concrete per unit volume are taken as 35000 MPa and 25.5 kN/m^3. Poisson ratio of concrete is υ = 0.20. In full tank condition, the tank level is 7 m. The container is filled with water (H_2O) of density density ρ_w = 1 000 kg/m^3. The bulk modulus is B = 2.1 10^9 N/m^2. As the excitation loading we consider horizontal earthquake load given by the accelerogram of the earthquake in Loma Prieta, California (18.10.1989). The water filled tank is grounded on fine sub-soil.

Time history analysis for Loma Prieta earthquake was carried out for the tank with full tank condition. The maximum base shear response of the tank is 1.33 MN. The maximum bending moment under Loma Prieta acceleration from time history analysis is 6.24 MNm [10,27].

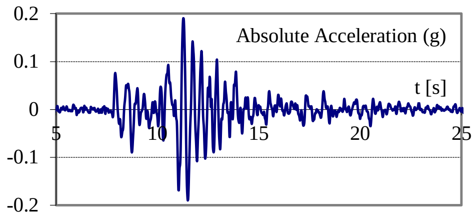

Fig. 1. Accelerogram Loma Prieta, California.

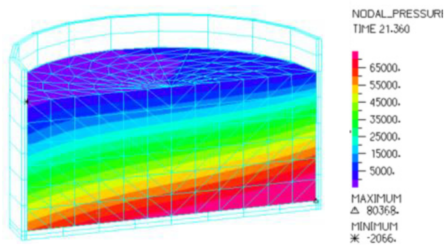

Fig. 2. Tank and hydrodynamic pressure of fluid filing.

3. Numerical Experiment of Soil/Structure Interactions (SSI)

The cylindrical tank is founded at depth of 0.5 m below the surface on the circular base with diameter of 7.5 m with a thickness of 0.5 m.

Previous research the subsoil has been modeled using 5 various types of gravel subsoil - soil group G1 to G5 [4]. Now we selected for soil-structure interaction two types of subsoil: gravelly silt (MG) and gravelly clay (CG). The concrete tanks have been analyzed on fine soils - group F1 and F2 [10]. The values of the geotechnical parameters of subsoil are given in the Table 1.

The concrete tanks - water reservoirs - resting on various subsoils have been analyzed. The subsoil has been modeled using two types of soil and three basic models - load conditions:

1. empty tank - static analysis,
2. water filled tank - static analysis,
3. water filled tank - seismic analysis.

The tank has been verificated according to theories of Limit States I. - the ultimate limit state (ULS) and II. - the serviceability limit state (SLS) under EC 7. It was computed vertical and horizontal bearing capacity, settlement and rotation of a footing [11].

The resulting deformation depends on the deformation properties of the subsoil (Table 1) and on the size of the tensions in the foundation soil - stress in soils (σ_{or}) and stress from the external load (σ_z). Stresses in the soil were determined according to the theory of elasticity (Boussinesq theory). When computing settlement below the footing bottom, the first is calculated the stress in the footing bottom and then is determined the overall settlement and rotation of foundation.

The general approach draws on subdividing the subsoil into layers of a different thickness based on the depth below the footing bottom or ground surface. Vertical deformation of each layer is then computed - the overall settlement is