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Analysis of Soil-Structure Interaction in Underground Water Tank Structures Considering Influence of Fluid

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Earthquake warnings occurred at Nuclear Power Plants (NPPs) and middle/low level nuclear facilities due to the 9.12 earthquake (maximum 5.8 scale, near Gyeongju City). Seismic measurement values were less than half of SSE (Safe Shutdown Earthquake, 0.2g), but Wolsung Units 1~4 were manually stopped because the response spectrum value exceeded OBE (Operating Basis Earthquake, 0.1g). Since the first operation of the earthquake response system after the beginning of operation of the NPPs, the National Assembly, local residents and CSO (Civil Society Organizations) have been demanding quick and accurate disclosure of the state of nuclear facilities. The Nuclear Safety Commission has proposed seismic capacity evaluation and seismic retrofitting of domestic NPPs and nuclear facilities as safety measures against large earthquakes. Therefore, it is necessary to accurately reevaluate the actual seismic capacity of core facilities of nuclear power plants, to confirm the seismic capacity according to major functions, and to reinforce them to improve safety against large earthquakes.

Nuclear fuel in reactors has a multi-barrier system to prevent external leakage. In order to prevent leakage of neutron beams, one kind of radiation, nuclear fuel is stored in a tank. When a seismic force is applied to the tank, the seismic force acting on the tank affects the fluid, and the movement of the fluid influences the tank again. This phenomenon is called Fluid-Structure Interaction (FSI). If seismic forces are applied to the tank storing nuclear fuel, the tank will be affected by the FSI effect. Recent interest in the study of underground nuclear facilities (KAERI, 2009) or underground research facilities involving radioactive waste has been growing (Seo, 2010). Underground nuclear facilities have advantages such as improvement of seismic safety, economic gain and easy closing. Especially, when an NPP or research reactor is constructed underground, the ground becomes a substitute for the containment building and safety is greatly increased. The purpose of this study is to analyze the influence of the fluid inside the tank on an underground tank structure.

In this study, dynamic analysis of underground tank structures considering the Soil-Structure Interaction (SSI) effect was performed and the results were compared. The analytical model is an underground structure as shown in Fig. 1. Three basins are located in the basement. Here, all the three water tanks are adjacent to each other, and the shape is the same as that of the rectangular tank. The tank was assumed to be full of water.

SSI analysis was performed using SASSI2010. In this paper, SSI analysis was performed using the direct flexible volume method of SASSI2010. Although this method requires extensive computer equipment specifications and a lot of analysis time, dynamic interactions can be calculated at all locations shared by the ground and the structure. Fig. 2 conceptually illustrates the modeling of the flexible volume method.

The PGA of the artificial seismic wave acting on the analytical model (Fig. 3, Fig. 4) is 0.2g, which satisfies the SSE, and is generated using Simqke (1971) and SHAKE91. The characteristics of the ground where the structure is located are shown in Fig. 5.

The fluid inside the tank was applied to the wall of the tank by dividing the dynamic behavior of the fluid as affected by the earthquake into an impulsive mode and a convective mode load (Sudhir et al., 2005). The fluid in the tank was represented by a spring-mass model as shown in Fig 6. The parameters of the spring mass model used here are as follows.

$$\frac{m_i}{m} = \frac{\tanh\left(0.866\frac{L}{h}\right)}{0.866\frac{L}{h}} \quad (1)$$

$$\begin{aligned} \frac{h_i}{h} &= 0.375 && \text{for } \frac{L}{h} \le 0.75 \\ &= 0.5 - 0.09375\frac{h}{L} && \text{for } \frac{L}{h} > 0.75 \end{aligned} \quad (2)$$

$$\frac{m_c}{m} = 0.264\frac{\tanh\left(3.16\frac{h}{L}\right)}{\frac{h}{L}} \quad (3)$$

$$\frac{h_c}{h} = 1 - \frac{\cosh\left(3.16\frac{h}{L}\right) - 1.0}{3.16\frac{h}{L}\sinh\left(3.16\frac{h}{L}\right)} \quad (4)$$

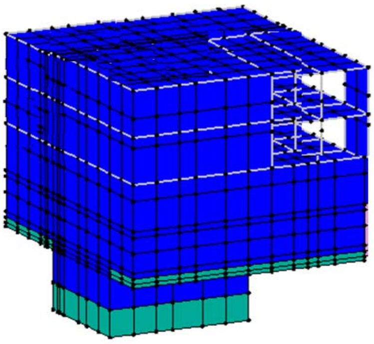

Fig. 1. Underground- tank structure

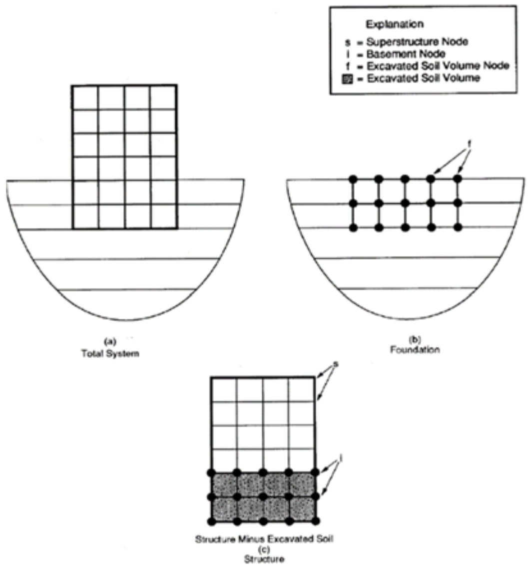

Fig. 2. Model structure of SASSI2010 flexible volume method

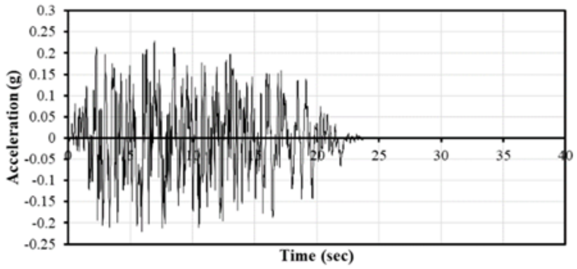

Fig. 3. Horizontal artificial acceleration time hysteresis curve

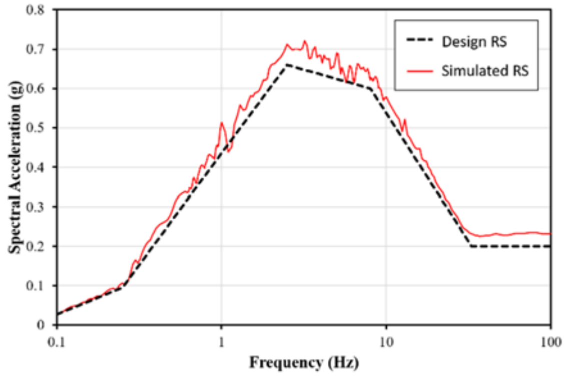

Fig. 4. Horizontal artificial acceleration response spectrum

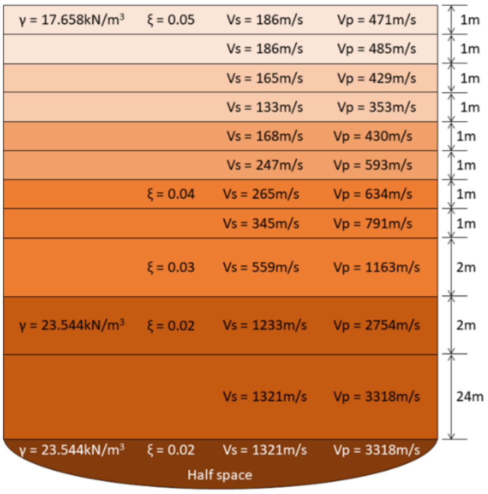

Fig. 5. Soil condition

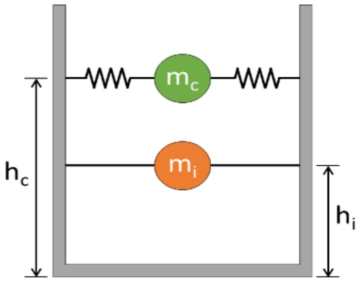

Fig. 6. Fluid dynamic characteristics

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