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Effects of Pool Dimension on Sloshing Height Caused by Earthquake

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1. Introduction

Pools are generally used for cooling and shielding radiation from research reactors or spent fuels. The pools are designed to maintain structural during earthquake. Sloshing motion of the water can be caused by the earthquake. The sloshing motions of water have been verified through various methods such as experiments, fluid-structure interaction (FSI) simulation, and analytical solution. Simple formula prepared for tanks supported on the ground in the TID-7024 report [1] is widely used to predict the sloshing height of the pool water by designers. In this work, we review the method of the TID-7024 report [1] and effects of rectangular pool dimension on the sloshing height are investigated.

2. Methods and Results

2.1 TID-7024 Procedure

In the TID-7024 report [1], the procedure for calculating the water-surface displacement of rectangular pool caused by an earthquake is as follows.

The natural frequency (of water), ω, is obtained from Eq. 1.

$$\omega^2 = \frac{1.58g}{L}\tanh\left(1.58\frac{H}{L}\right) \quad (1)$$

where g is acceleration of gravity, L is one-half length of rectangular pool wall, and H is height of water surface above the bottom of the pool.

The quantity S may be obtained from the calculated natural frequency for the appropriate damping. In the example of the TID-7024 report [1], the value of S is obtained from the average-velocity-spectrum curves of the intensity of ground motion recorded at El Centro, Calif., 1940, using the natural frequency value, ω, and 0.5% critical damping. The quantity S designates the spectral velocity for the natural frequency of water in the pool.

Using S, the maximum amplitude, A_1, of the displacement (of water) is computed. In the example of the TID-7024 report [1], A_1 is calculated using Eq. 2.

$$A_1 = \frac{S}{\omega} \quad (2)$$

The angle of free oscillation, θ_h, at the water surface is obtained from Eq. 3.

$$\theta_h = 1.58\frac{A_1}{L}\tanh\left(1.58\frac{H}{L}\right) \quad (3)$$

The maximum water-surface displacement, d_{max} (above its original level) from Eq. 4 and the values of ω and θ_h.

$$d_{\max} = \frac{0.527L\coth\left(1.58\frac{H}{L}\right)}{\frac{g}{\omega^2\theta_h L} - 1} \quad (4)$$

2.2 Spectral Acceleration Approach

The maximum amplitude of the displacement, A_1, designates the spectral displacement, S_D in Eq. 2. Equation 5 shows the mutual relationships of pseudo values; displacement, velocity and acceleration.

$$A_1 = S_D = \frac{S}{\omega} = \frac{S_A}{\omega^2} \quad (5)$$

The spectral acceleration, S_A, can be obtained from response spectrum curves for the natural frequency of pool water, ω, and 0.5% critical damping. From this relationship, Eq. 4 is re-written and d_{max} is calculated from L, H/L, and S_A.

$$d_{\max} = \frac{0.527L}{\frac{g}{1.58S_A} - \tanh\left(1.58\frac{H}{L}\right)} \quad (6)$$

2.3 Effects of Pool Dimension

Figure 1 shows the natural frequency of water in the rectangular pool as a function of the pool length for different pool water depth to pool length ratios, H/L=0.5, 1, and 2. The natural frequency of water decreases as the pool length increases. The natural frequency of water increases as H/L increases. However, the effects of H/L on the natural frequency is negligible when H/L < 1. When the pool length is longer than 4 m (L>2 m), the natural frequency of water is below 0.5 Hz.

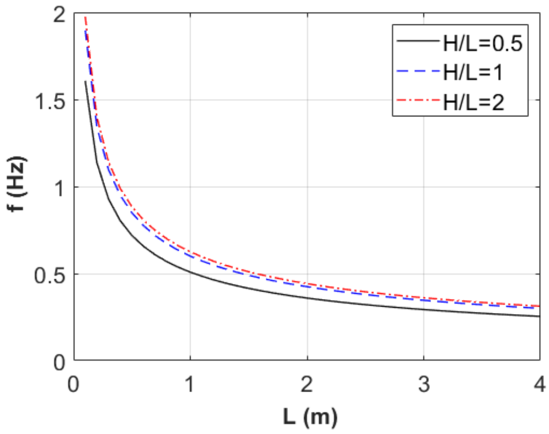

Fig. 1. Natural frequency of pool water as a function of the pool length for different water depth to pool length ratios.

Figure 2 shows the maximum water-surface displacement as a function of the spectral acceleration for different pool lengths, *L*=1, 2, and 4 m. The pool water depth to pool length ratio is *H/L*=1. The maximum water-surface displacement increases as the spectral acceleration increases and it increases as the pool length increases.

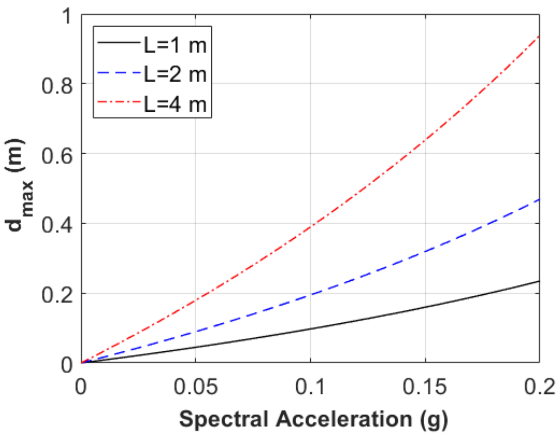

Fig. 2. Maximum water-surface displacement as a function of the spectral acceleration for different pool lengths.

Figure 3 shows the maximum water-surface displacement as a function of the spectral acceleration for different pool water depth to pool length ratios, *H/L*=0.5, 1, and 2. The one-half length of the pool is *L*=4 m. The maximum water-surface displacement increases as the water depth to pool length ratio increases. However, the effects of the *H/L* on the maximum water-surface displacement is negligible for *H/L* > 1.

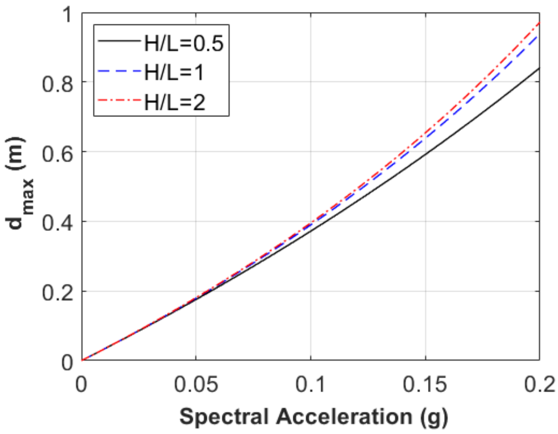

Fig. 3. Maximum water-surface displacement as a function of the spectral acceleration for different water depth to pool length ratios.

3. Conclusions

Equations presented in the TID-7024 report for calculating the maximum water-surface displacement are modified to use the spectral acceleration value from the response spectrum curve. Effects of the pool length and the water depth ratio on the natural frequency of the pool water and the sloshing height are investigated. The natural frequency of the pool water decreases as the pool length increases. The sloshing height increases as the pool length or the water depth to pool length ratio increases. Effects of the water depth to pool length ratio is smaller than that of the pool length.

Acknowledgment

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REFERENCES

[1] T. H. Thomas, G. Yasui, R. H. Graham, R. A. Williamson, R. E. Lowe, W. Hoak, "Nuclear Reactors and Earthquakes", TID-7024, U.S. Atomic Energy Commission, 1961.