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Dynamic Analysis of Plate in Water Tank

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1. Introduction

A pool door (Plate) is installed at the chase of the pool gate by means of an overhead crane in the building of a research reactor. The principal function of the pool door, which is located between the reactor pool and service pool, is to separate the reactor pool from the service pool for the maintenance and/or the removal of the equipment either in the reactor pool or service pool. The configuration of the pool door is shown in Figure 1. In this paper, the FEM(Finite Element Method) analysis were performed to evaluate the natural frequency for the pool door in the water, and the impulsive force and convective force of the pool tank during an earthquake were calculated for an estimation of the structural integrity of the pool door.

Figure 1 Configuration of the pool door

2. Methods and Results

A calculation was conducted to evaluate the structural adequacy of the pool door for the required design loadings. Static and dynamic analyses were used for a structural evaluation. The equivalent static analysis is employed as a dynamic analysis method. Since the pool door of Figure 1 is located between the reactor pool and the service pool, the impulsive force and convective force of the service pool during an earthquake must be calculated for that of the pool door. When a tank containing a fluid of weight W is accelerated in a horizontal direction, a certain portion of the fluid acts as if it were a solid mass of weight W_0 in rigid contact with the walls. Assuming that the tank moves as a rigid body, with the bottom and walls undergoing the same acceleration, the mass then exerts a maximum horizontal force directly proportional to the maximum acceleration of the tank bottom. This force is identified as an impulsive force, P_0. The acceleration also induces oscillations of the fluid, contributing additional dynamic pressures on the walls and bottom, in which a certain portion of the fluid, of weight W_1, responds as if it were a solid oscillating mass flexibly connected to the walls. Again assuming that the tank itself behaves as a rigid body, the maximum amplitude, A_1, of the horizontal excursions of the mass relative to the walls determines both the maximum vertical displacement, d_{max}, of the water surface (slosh height) and the horizontal force exerted on the walls. This force is defined as a convective force, P_1, since it involves fluid motion. The pool door is located between the reactor pool and the service pool. The water depth is 10 m. The types of loads considered are dead loads, hydrostatic loads, hydrodynamic loads, and seismic loads. The seismic loads are the loads experienced by the system during the SSE. The effect of these loads is evaluated using the floor response spectrum (SSE; Safe Shutdown Earthquake, 7% damping) curves. For example, Figure 2 is the E-W FRS(East-West Floor Response Spectrum of the top area of the reactor pool (SSE, 2%, 3%, 4%, 5%, 7%, 10% damping).

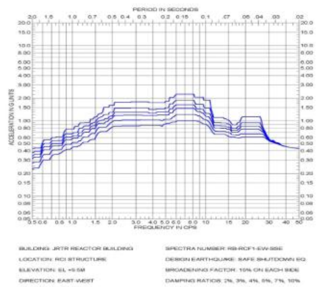

Figure 2 E-W FRS of the top area of the reactor pool (SSE, 2%, 3%, 4%, 5%, 7%, 10% damping)

2.1 Material and Property

All loads bearing structural steel shall conform to ASTM Specification A240-TP 304L. The yield stress, tensile stress and allowable stress for ASTM A240-TP 304L are as follows [1].

Material Property	**ASTM A 240-TP 304L**
Modulus of Elasticity	1.952E+11 N/m^2
Poisson's Ratio	0.30
Mass Density	7900 kg/m^3
Yield Strength (σ_y)	172 MPa
Tensile Strength (σ_u)	483 MPa
Allowable Stress (σ_a)	Normal Condition ;1.0 σ_a (115 MPa) Severe Condition ; 1.6 σ_a (184 MPa)

2.2 Natural Frequency by FEM

The natural frequencies of the pool door were obtained from an analysis using the ANSYS code. The pool door was modeled using SHELL 63 element and the water in the pool was modeled using FLUID80 element. The finite element model by the ANSYS code is shown in Figure 3. The boundary condition at the plate edge is assumed to be completely simply supported (S-S-S-S).

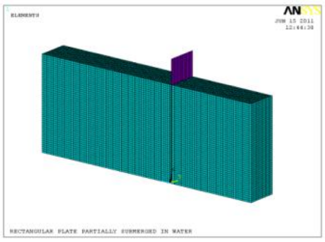

Figure 3 ANSYS model for the pool door

The deformed shape of the 1st mode is shown in Figure 4.

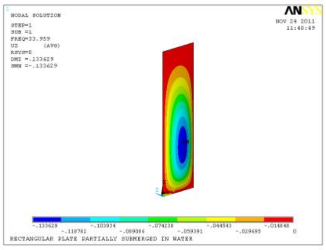

Figure 4 The 1st mode of the pool door

The results of the modal analysis are as follows.

Mode	Natural frequency (Hz)
1	33.96
2	55.78
3	82.07
4	114.14
5	151.14

2.3 Stress Analysis

The dynamic model of the service pool is shown in Figure 5.

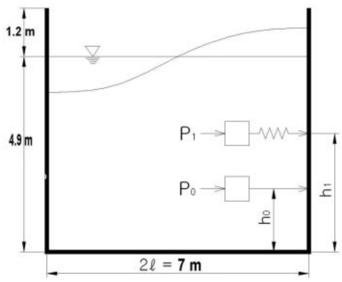

Figure 5 Dynamic model for non-slender tank

h/l=(height of tank/length of tank) = 16.076/11.483 = 1.4

Since the h/l value is smaller than 1.5, this is a non-slender tank. The impulsive Force (P_0) and Convective Force (P_1) are calculated by a formula [2]. For an equivalent static analysis, horizontal (0.52g) and vertical (0.45g) acceleration are applied.

- Fx=Horizontal seismic loads = HSL= ma = 1.5x3000 x 0. 52 g = 22932 (N)
- Fz =Horizontal seismic loads = HSL= ma = 1.5x3000 x 0. 52 g = 22932 (N)
- Fy =Vertical seismic loads = VSL= ma = 1.5x3000 x 0.4 5 g = 19845 (N)

After the load combination, the loads are calculated as follows.

Fy= Dead load + Vertical seismic load = 29400+19845 = 49245(N)

Fx= Horizontal seismic load= 22932 (N)

Fz= Hydrostatic Load+ Hydrodynamic Load +Horizontal seismic load=185886+18350(Convective Force) + 128878(Impulsive Force) + 22932= 356046(N)

The maximum load applied to each component of the pool door is

$F = \sqrt{F_v{}^2 + F_y{}^2 + F_z{}^2} = \sqrt{49245^2 + 22932^2 + 356046^2} \fallingdotseq 360166$ (N)

For example, the bending stress for corrugated plate is as follows.

$\therefore \quad \sigma = (M \times y)/ I_Z = 47.38$ MPa

The results of the static and seismic analysis for each component of the pool door were lower than the design limits(1.0 σ_a (115 MPa), 1.6 σ_a (184 MPa))for the given material.

3. Conclusions

A stress analysis for each component of the pool door was conducted against the given loads including the seismic load. Because the stresses for the analysis results were lower than the design limits for the given material, the structural integrity for the given dimension of the pool door was confirmed.

Acknowledgements

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REFERENCES

[1] Annual Book of ASTM, American Society for Testing Materials.

[2] United States Atomic Energy Commission (1963) TID-72 04 Nuclear Reactors and Earthquakes, Chapter 6 Dynamic Pre ssure on Fluid Container.