Structural Integrity of the Stiffened Rectangular Plate in a Fluid

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1. Introduction

Stiffened rectangular plate, installed as a part of pool liner without the concrete support (Safety Class 3), is designed considering the neutron absorption during normal operation and structural integrity during and after seismic events.

Fig. 1 shows the design of stiffened rectangular plate. According to design requirements, irradiation area part has 9 mm thickness and other parts of that area have stiffened structures. In this study, structural integrity for the stiffened rectangular plate is evaluated as a part of pressure vessel and as a part of fluid containers respectively.

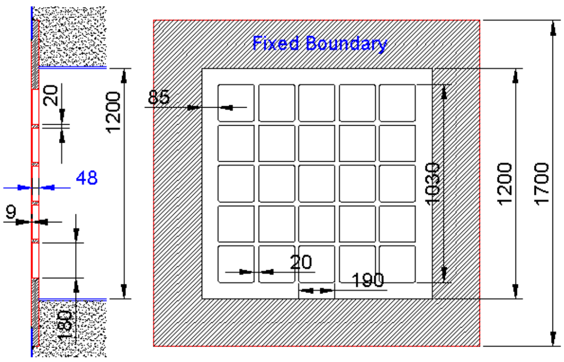


Fig. 1 Model of Stiffened Rectangular Plate

2. Design of Stiffened Rectangular Plate

2.1 Wall Thickness

Type 304L stainless steel is chosen to apply the same material as that of pool liner. The minimum thickness of the pressure vessel according to the ASME ND-3324.3 [1] has been expressed as:

$$t = \frac{PR}{SE - 0.6P} \quad (1)$$

Where,

P: design pressure (0.15MPa)
R: inside radius (1.8m)
S: maximum allowable stress value (115MPa)
E: joint efficiency (0.8, circum. joint, spot examined)

The designed thickness 9mm is greater than the calculated thickness 5.88mm.

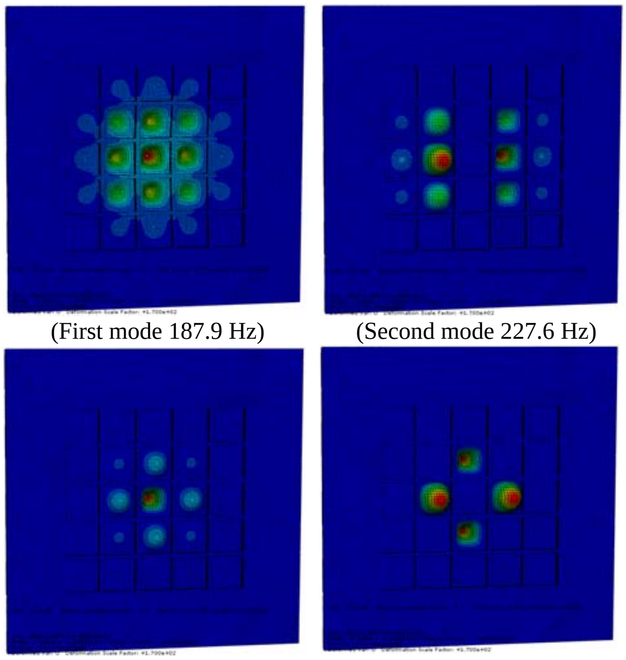
2.2 Modal Analysis

8-node solid element (C3D8) in ABAQUS 6.4 [2] is applied to the whole model. Boundary condition is shown in Fig. 1 and material properties are given at Table 1.

Table 1 Material properties of SS 304L

Young's Modulus	Mass Density	Possion's Ratio	Yield Strength
195 (N/mm^2)	7.97E-9 ($N\ sec^2/mm^4$)	0.27	172 MPa

The first natural frequency of stiffened rectangular plate in air is greater than ZPA frequency (50 Hz) as shown in Fig 2. Even though added mass effect for the rectangular plates with one side exposed to fluid proposed by Greenspon [3] is considered, its first natural frequency is greater than ZPA frequency.



(First mode 187.9 Hz) (Second mode 227.6 Hz)
(Third mode 230.4 Hz) (Fourth mode 232.2 Hz)

Fig. 2 Mode Shape of Stiffened Rectangular Plate

So the stiffened rectangular plate can be analyzed "rigidly" using equivalent acceleration.

For the equivalent static analysis, seismic loading is 0.41g and 0.51g applied in two horizontal orthogonal direction, plus 0.45g vertical, plus gravity, with a 150% margin.

3. Stress and Deflection

3.1 Dynamic Pressure

The horizontal acceleration of a fluid container generates horizontal hydrodynamic forces acting outward on one side of the tank and inward on the opposite side. These forces are composed of impulsive force and convective force.

For the simplified calculation of dynamic pressure, the model is assumed as a slender cylindrical tank [4]. This model with 1.8m radius and 10m water depth has 7.3m constrained water depth, which moves as a completely constrained fluid.

Since the stiffened rectangular plate is located below the 7.3m, only the impulsive forces are considered as a dynamic pressure and the distance between the stiffened rectangular plate and in-pool structure is regarded as 1m conservatively (considering the absence of in-pool structure between the reactor structure assembly and stiffened rectangular plate) for the fluid volumes.

3.2 Modeling and Load Combination

The FE Model and the material properties are the same as given in paragraph 2.2. The load combinations on the components are as follows;

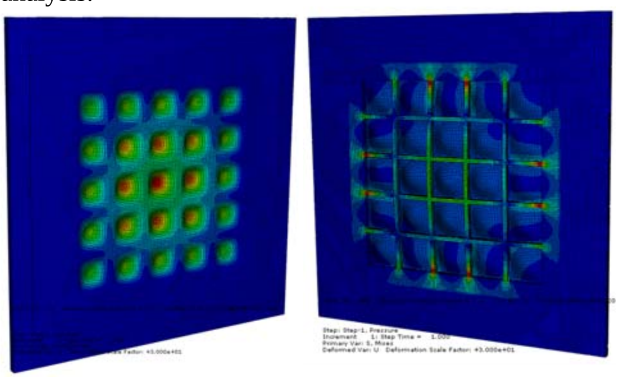
- Weight of stiffened rectangular plate
- Hydro-static pressure
- Hydro-dynamic pressure

3.3 Results

The maximum deflection, about 2.65mm, is occurred in the center of stiffened rectangular plate and shows that this deflection does not go beyond the boundary of stiffener's height 39mm. Also the maximum deflection of 0.96mm in the stiffener shows that stiffened rectangular plate is not contact with the adjacent structure.

The highest stress 121.3 MPa, occurred at the edge of stiffener part, is lower than the yield strength 172 MPa.

Fig. 3 shows the deflection and stress results of FE analysis.



(Deflection) (Von-Mises Stress)

Fig. 3 Stress and Displacement of the Model

4. Conclusions

The stiffened rectangular plate design is reviewed as a part of pressure vessel and as a part of fluid containers, respectively.

Designed wall thickness is greater than the ASME III ND code requirements. The resonance is not anticipated in this structure during the seismic events because the first natural frequency is much greater than the ZPA frequency.

Hydro-dynamic pressure and the hydro-static pressure are calculated for the evaluation of structural integrity of stiffened rectangular plate as fluid containers. The stiffened rectangular plate is expected to maintain structural integrity as well as not to interface with surrounding structures due to the deflection.

REFERENCES

[1] ASME B&PV Section III Div. 1 Sub-section ND, 2007.
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[3] J. E. Greenspon, Vibrations of cross-stiffened and sandwich plates with application to underwater sound radiators, Journal of Acoustic Society of America 33, 1485-1497, 1961
[4] TID-7024, Nuclear Reactors and Earthquakes, Chapter 6 Dynamic Pressure on Fluid Containers, August 1963.