Structural Integrity Evaluation of a Service Pool Working Platform in Research Reactor

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1. Introduction

Underwater platforms are installed in the service pool of research reactor. For the workability in the service pool, elevated working platform with enough area is required. For this purpose, the service pool working platform (SPWP) is designed so as to provide the handling space for RI cask, support the RI working table, support the fuel basket and provide the handling space for the objects related to the neutron transmutation doping (NTD).

The objective of this paper is to perform seismic analyses and evaluate the structural integrity of the SPWP. For this purpose, 3-D finite element model of the SPWP is developed and its modal analyses are carried out for analyzing the dynamic characteristics. Then response spectrum analyses and the related safety evaluation are performed for the SPWP subjected to seismic loads.

2. Design of Service Pool Working Platform

The SPWP is composed of frames and gratings. Embedded plate and stud bolts for platform installation are basically needed at the one side of the pool liner in research reactor. There are base frames along the periphery of the pool liner. The base frames are mounted by bolting on the embedded plates of the pool liner. On the frames, there are removable gratings to support the racks and workers.

3. Modeling of Service Pool Working Platform

The 3-D finite element model of the SPWP in Fig. 1 is developed by utilizing MIDAS CIVIL program. All parts of the SPWP structure is modeled as beam elements, distributed masses and point masses. For modeling of the beam structure of the SPWP, beam element which has total six translational and rotational degrees of freedom along each coordinate system is used. The weights of structural members, dead load and part of the live load are considered as the distributed masses.

In addition, since the SPWP is submerged in water, the “hydrodynamic mass” effect is taken to account. The hydrodynamic masses are calculated by considering the mass of the water surrounding H-beams and angles. And these are considered as the point masses in the finite element model.

The boundary conditions of the SPWP are shown in Fig. 1. The displacement fixed and rotation freed boundary conditions are imposed on the end of the SPWP since it is bolted to the bracket contacted in the embedded plate. Most parts of the SPWP are made up as stainless steel 304L.

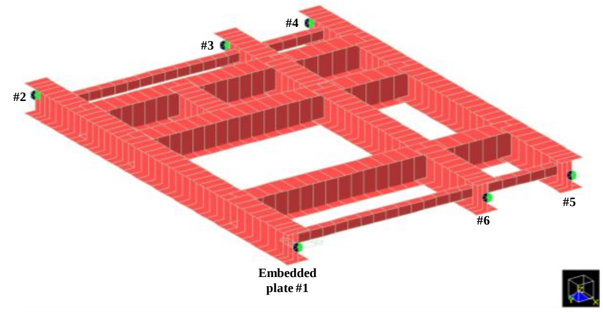
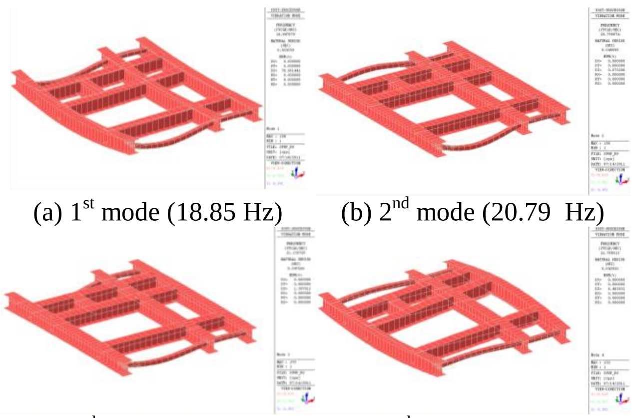


Fig. 1 3-D finite element models of the SPWP

4. Modal Analysis

In order to investigate the dynamic characteristics of the SPWP, modal analysis of the developed finite element model is performed. The typical measure of the dynamic characteristics, natural frequencies and mode shapes are obtained. Fig. 2 summarizes four mode shapes in the structural model of the SPWP. It can be observed that the first natural frequency, the structurally fundamental frequency is 18.85Hz.



(a) 1st mode (18.85 Hz) (b) 2nd mode (20.79 Hz)

(c) 3rd mode (21.16 Hz) (c) 4rd mode (22.77 Hz)

Fig. 2 Natural frequencies and mode shapes of the SPWP

5. Seismic Analysis of Service Pool Working Platform

The response spectrum analysis has been performed to evaluate the structural responses of the SPWP under the safe shutdown earthquake (SSE). Total 50 modes are considered for the modal response combination to take into account a modal effective mass of 90% of the model, and the square root of the sum of the squares (SRSS) method is used to combine the total response in each mode and direction. [1]

5.1 Dead, Live and Seismic Loads

The weight of main beams such as H-beams/angles and the checkered plates/the grating is about 1000kg and about 830kg, respectively. The live load acting on the SPWP is 1000kg/m^2. The enveloped floor response spectra for SSE at the installing position of the SPWP are shown in Fig. 3. The 7% damping is used for the horizontal and vertical floor response spectra.

5.2 Load Combinations

According to KEPIC SND code [2], two load combinations are used in the SPWP.

Table 1 Load Combinations of SPWP

Cases	Load Combinations	Allowable Values
Normal	Dead Load + Live Load	U
Extreme environmental	Dead Load + Live Load + SSE	1.6U

Where U denotes allowable stress.

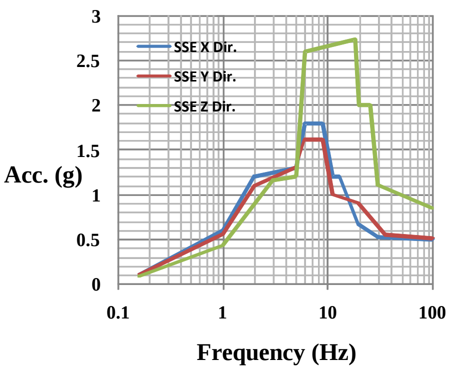


Fig. 3 Floor response spectra for SSE (0.3g)

5.3 Evaluation of the Structural Integrity

For the estimation of the structural integrity of the beam elements of the SPWP, in accordance with KEPIC SND code, following conditions are applied.

(1) Allowable stress (F_y : yield, F_t : tensile, F_a : compression, F_v : shear, F_b : bending, kl/r : slenderness ratio)

$$F_t = 0.6F_y$$

$$F_a = \frac{F_y}{2.15} - \left[\frac{\frac{F_y}{2.15} - 6}{120}\right]\frac{kl}{r}, \quad \frac{kl}{r} < 120$$

$$F_v = 0.4F_y$$

$$F_b = 0.6F_y$$

(2) Combined stress ratio (S.R.)

$$\frac{f_t}{F_t} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \le 1.0$$

Where f_t denotes the calculated tensile stress. f_{bx} and f_{by} denote the calculated bending stress in the x and y direction. $F_{bx} = F_{by} = F_b$.

5.4 Analysis Results

Tensile, shear, and combined stresses of each the SPWP are estimated. Then, the maximum stresses of the SPWP under normal and extreme environmental loading conditions are obtained. The results show that the weakest case is made in the angle elements (between 2&3 and 1&5 embedded plate) of the SPWP and maximum stresses of the SPWP are summarized in Table 2.

These analysis results show that maximum tensile, shear, and combined stresses under any loading conditions are within the KEPIC code limits. Thus, we can confirm that any damage on the structural integrity of the SPWP structure is not expected.

Table 2 Maximum stress of SPWP

	Maximum stress (MPa)						
	Calculated				Allowable		
	F_t	F_v	F_b	S.R.	F_t	F_v	F_b
Normal	0	12	80	0.65	124	50	124
Extreme environmental	1	25	148	0.79	198	115	198

6. Conclusion

The structural integrity of the SPWP under normal and extreme environmental loading condition has been evaluated. For this purpose, 3-D finite element models of the SPWP were developed. Then, static analysis, modal analysis and response spectrum analysis were performed.

From the structural analysis results, it is concluded that the SPWP meets the structural design limit stated in the KEPIC code.

REFERENCES

[1] US NRC Regulatory Guide 1.92, Combining Modal Responses and Spatial Components in Seismic Response Analysis, 2006.
[2] KEPIC, SND, Safety-Related Steel Structures for Nuclear Facilities, 2005.