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Seismic Capacity Assessment of Spent Fuel Bay for Wolsong NPP

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1. Introduction

The spent fuel bay (SFB) plays the role of storing in the water storage pit the spent fuels used in the reactor building by withdrawing them. SFB is located in an auxiliary building; it is a reinforced concrete structure consisting of reception pit, spent fuel pit, and defective fuel storage pit. This study performed seismic analysis at the level of 0.2g as basis for earthquake design, in order to evaluate the seismic safety of SFB and the results were described.

2. SFB Seismic Analysis Model

2.1SFB Shape

SFB is a reinforced concrete structure measuring 32m ×19m × 9m and consisting of reception pit, spent fuel pit, and defective fuel storage pit. The size is shown in Fig. 1 and Table 1. The surrounding of SFB was connected to the part adjoining the containment vessel and ground.

Table 1 Size of SFB structure

Area	Size (m)
Spent Fuel Pit	12 × 20
Reception Pit	8.69 × 3.66
	3.2 × 82., 3.53 × 3.66
Defective Fuel Pit	5.5 × 2.4

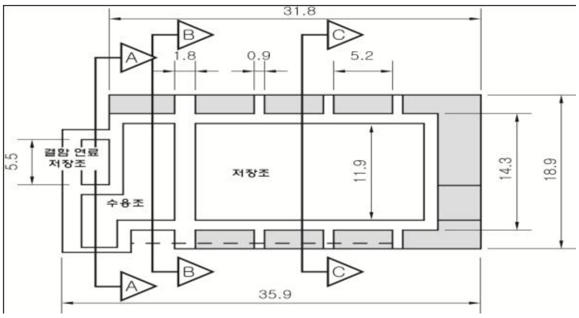

Fig. 1 Sectional View of SFB

2.2 SFB Seismic Analysis Model

The analytical model of SFB widely considers three fields (i.e., concrete, fluid, and ground) as shown in Fig. 2. To consider the characteristics of the containment vessel adjoining the reception pit and the structures adjoining the containment vessel, the steel element was included. Three-dimensional, 8-nodal point solid element supported in ANSYS and Fluid 80 element were used for the concrete and ground, respectively. The ground field was basically determined to be triple the size of the bay.

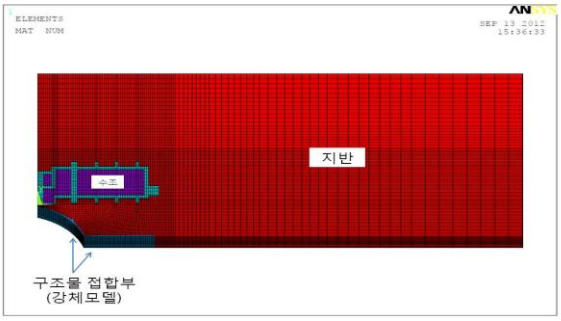

Fig. 2 SFB Seismic Analysis Model

2.3 Boundary Condition

For the boundary condition of the analysis model, the three directions at the lower part in the model were given as the fixed end. The condition in the boundary surface between concrete element and fluid element was determined, i.e., the coupling condition between nodes was applied to the elements, the normal direction was confined, and the free surface condition (slip occurs) was applied in the surface direction. For the boundary condition on the ground field, the connecting part between pit and ground was connected and treated as continuous structure. The free node condition was applied to the opposite ground of the bay. It should be noted that the steel element was included at the connecting parts to the containment building and other structures to consider the characteristics of the structures.

Table 2 Material Properties

Type	Modulus of Elasticity (MPa)	Poisson's Ratio	Density (kg/m^3)	Damping Ratio (%)
Fluid	2.0×10^3	0.499	1,000	0.5
Concrete	2.8×10^4	0.167	2,300	5
Ground	5.2×10^2	0.45	2,000	4

2.4 Material Properties

The interior of SFB is coated with epoxy resin liner to block the external release of the fluid. In this analysis, the steel and epoxy resin liner were excluded; the concrete, fluid, and ground were considered instead. The properties of these materials are shown in Table 2.

2.5 Input Seismic Wave

FSSI was performed by time history analysis using a direct integration method to evaluate the seismic safety of SFB against seismic load at the DBE level. The standard response spectrum of the CSA standard -- a basis for earthquake design -- was used as the input seismic motion by referring to [1] at this time. Artificial seismic wave was applied at the same time in three directions at the lower part of the analysis model.

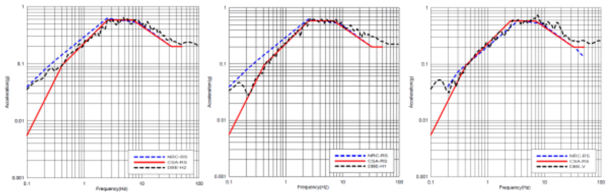

Fig. 2 DBE Response Spectrum: (Left) E-W, (Center) N-S, and (Right) Verticality

3. Seismic Analysis Result

As shown in Fig. 3, the displacements and maximum stresses were analyzed at major points. Displacement was obtained as relative displacement on the basis of the lower structure in SFB. The maximum phase displacement occurred at the 9-point location shown in Fig. 3. The displacements at each direction were x = 0.77mm, y = 1.23mm, and z = 0.46mm (see Fig. 4).

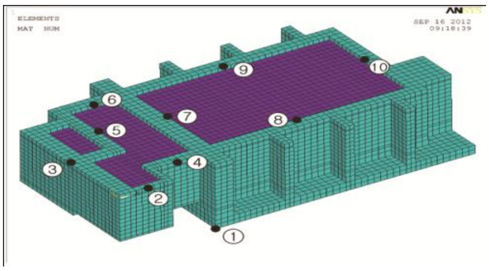

Fig. 3 Displacement Review Position

The maximum tensile stress, compressive stress, and shear stress were compared with the initial stress state associated with the self-load analysis as an initial condition. As a result, the maximum tensile stress occurred at the side section at the lower structure in the reception pit, and maximum compressive stress occurred at the lower part of the wing wall of the outer side of the spent fuel pit. Fig. 5 shows the maximum stress contour map of the concrete.

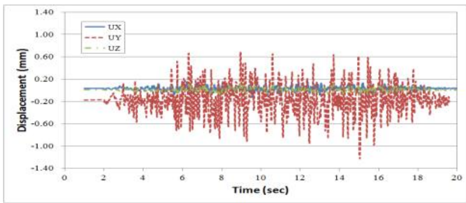

Fig. 4 Maximum Relative Displacement-Time History

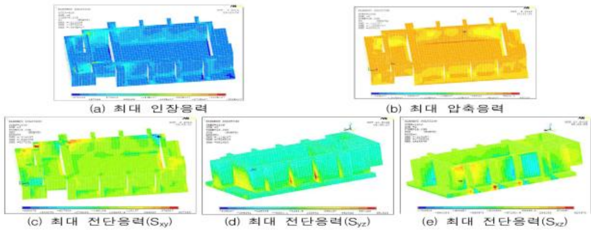

Fig. 5 Maximum Stress Contour Map of Concrete

The allowable stress of KEPIC SN nuclear structure [2] was compared for the review of each stress component. The stress review result is shown in Fig. 6. Sufficient safety margins were judged to have been secured with regard to compression, tension, and shear.

구 분		해석결과		허용응력	안전율
		초기 응력	최대 응력		(허용응력/최대응력)
인장응력 (Max. S1)		1.419 MPa	2.669 MPa	3.334 MPa [$0.63\sqrt{f_{ck}}$]	1.25
압축응력 (Min. S3)		1.001 MPa	3.911 MPa	11.200 MPa [$0.4f_{ck}$]	3.85
전단 응력	SXY	0.174 MPa	0.577 MPa	1.587 MPa [$0.3\sqrt{f_{ck}}$]	2.75
	SYZ	0.214 MPa	0.694 MPa		2.287
	SXZ	0.237 MPa	0.674 MPa		2.355

Fig. 6 Stress Review Result

4. Conclusion

This study performed seismic analysis at the DBE level in spent fuel bay. As a result of the seismic analysis, sufficient seismic safety was verified to have been secured at the DBE level.

ACKNOWLEDGMENT

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REFERENCES

[1] Korea Hydro & Nuclear Power Co., Ltd. (2008). "Report on the solution of exemption components of the seismic suitability evaluation."
[2] Korea Electric Association (2007). "SN Nuclear Structure." KEPIC.