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Seismic Analyses of Spent Fuel Storage Rack for Research Reactor

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1. Introduction

Spent Fuel Storage Racks (SFSR) are designed to preserve the spent fuel of research reactor safely in the spent fuel storage pool. Under the seismic excitations, the free-standing SFSRs could be slipped, and collided with adjacent structures and components such as pool liner. The structural integrity of SFSRs should be maintained under those conditions.

In this paper, 3-dimentional non-linear time history analyses of SFSRs were performed to check the structural integrity under the postulated seismic event. Hydrodynamic mass and coefficient of friction were examined with analyses results. Simulations were carried out by using the commercial software, ANSYS.

2. Analysis model and method

2.1 Analysis Model

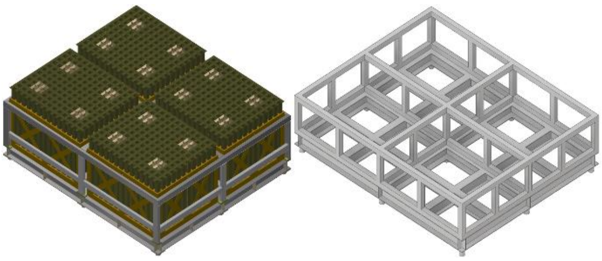

Fig. 1. Schematic and numerical model of the SFSRs

Fig. 1 depicts the schematic and numerical model of the SFSR, respectively. The SFSRs are composed of three types of spent fuel racks. To reduce the numerical cost, spent fuel assembly, cell pipes as well as attachments were regard as added mass on the SFSRs. Total mass of the SFSRs and attachments are about 26,000 kg. The numerical model was constructed with 770,156 nodes and 370,256 elements.

2.2 Hydrodynamic Mass

As the SFSRs are located in the pool, hydrodynamic mass should be calculated to consider the dynamic characteristics. For this matter, fluid in the gap between fuel assemblies and cell pipes, SFSR and support frame, as well as vacancies was calculated by the representative equations [1]. The calculated values were considered with added mass method in each direction. To quantifying the effect of the hydrodynamic effects, representative 3 values were examined. In addition, buoyancy were generally applied with all structures.

2.3 Coefficient of Friction

The coefficient of friction is important to determining the behavior of SFSRs under contact conditions. *Rabinowitz* suggested to be used the value of friction coefficient between 0.2 and 0.8. [2] In this study, 0.2 and 0.8 were selected as static friction coefficient to examine those effects. Generally, the static coefficient of friction is higher than the dynamic coefficient of friction, which are dependent on the relative velocity. To consider the static and dynamic friction behavior of structure, friction decay were considered with an appropriate assumption. The SFSRs have 9 level foot, and contacted with pool bottom under the free-standing conditions.

3. Analysis Conditions

3.1 Loading and Boundary Conditions

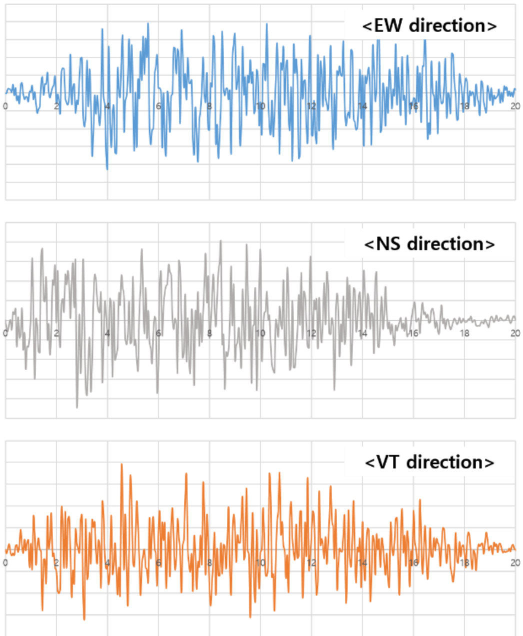

Fig. 2. Postulated seismic data

Fig. 2 shows the postulated seismic time history data with each direction. The transient data were simultaneously adopted on the SFSRs. Bottom of pool liner was fully fixed. Standard earth gravity was also considered in the whole model.

Analysis time were set to 20.5 sec, and each time step was 0.05 sec. The contact regions were modeled with contact elements. Rayleigh damping values were applied with calculation of modal analyses results.

3.2 Analysis Cases

Table I summarizes the analysis cases in this paper. 6 cases were selected to quantifying the hydrodynamic effects and coefficient of friction. In Cases 1-2, from a conservative point of view, hydrodynamic mass is not considered. In cases 3-4, hydrodynamic mass calculated by section 2.2 is applied. To check the dynamic mass effect with increasing the mass, 160 % of the calculated mass is adopted in cases 5-6.

Table I: Analysis Cases

No.	Hydrodynamic mass (kg)	COF
1	N/A	0.2
2		0.8
3	10,000	0.2
4		0.8
5	16,000	0.2
6		0.8

4. Analysis Results

Fig. 3 represents the displacements of the SFSRs under the postulated seismic condition at case 1. Since the hydrodynamic mass was not adopted, the maximum values were calculated.

Table II summarizes the maximum values of displacements at each case. As the hydrodynamic mass were increased, the displacements of SFSRs were decreased. Subsequently, the coefficient of friction was highly dominant on the behavior of SFSRs. The calculated gap distances between the SFSR and pool liner wall were enough to withstand the postulated seismic load. Fig. 4 shows the displacements history in case 1 at each direction.

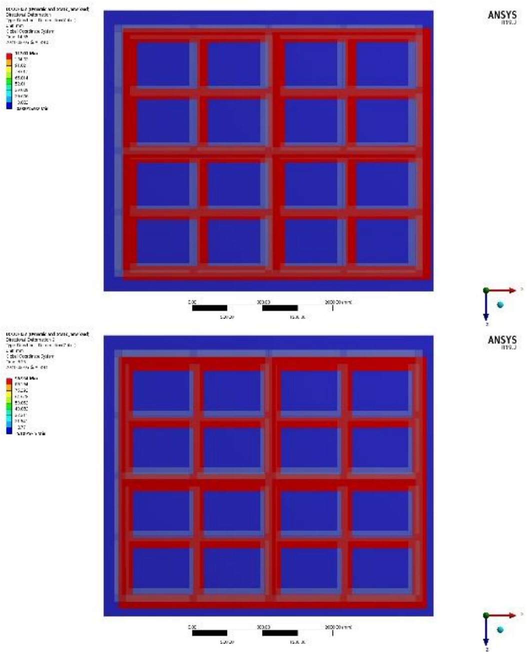

Fig. 3. Displacements distributions in case 1

Table II: Maximum displacements

No.	Maximum EW direction displacements (mm)	Maximum NS direction Displacements (mm)
1	117.03	96.93
2	13.39	5.50
3	71.08	49.56
4	4.66	6.32
5	63.48	49.16
6	4.89	8.52

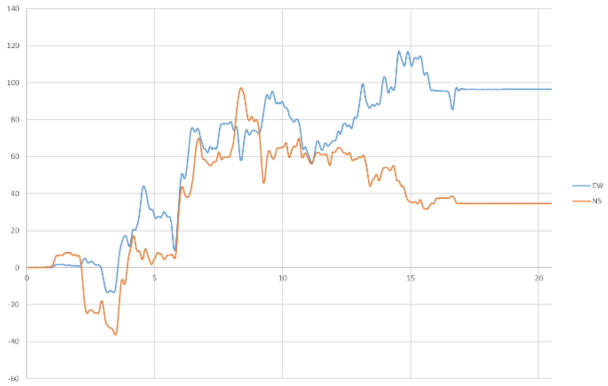

Fig. 4. Displacements histories in case 1

5. Conclusions

In this paper, nonlinear time history analyses of SFSRs were performed under the postulated seismic condition and following conclusions were derived.

(1) Maximum value of displacements were 117.03 mm in case 1 with EW direction, and the maximum displacements were decreased when the hydro-dynamic mass was increased.
(2) In all cases, the friction coefficient is affected to dynamic behavior of SRSRs with increasing the friction force.

ACKNOWLEDGEMENTS

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