Seismic Analyses of Spent Fuel Storage Rack for Research Reactor

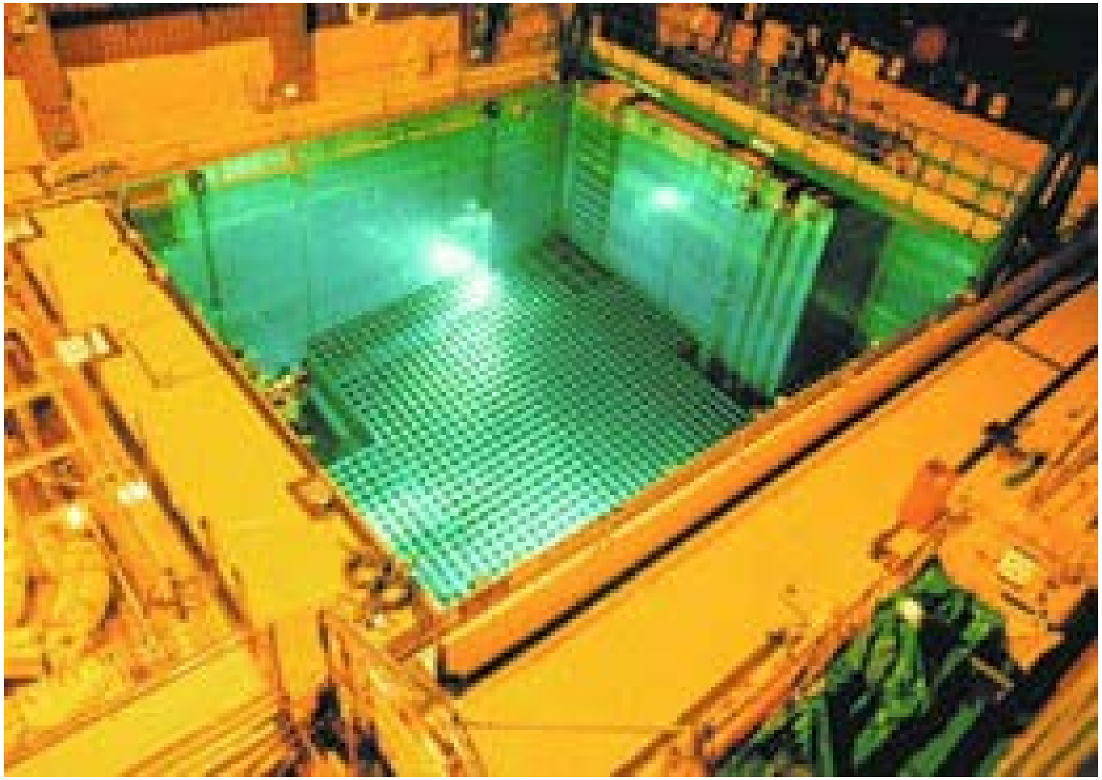
- Poster Presentation -

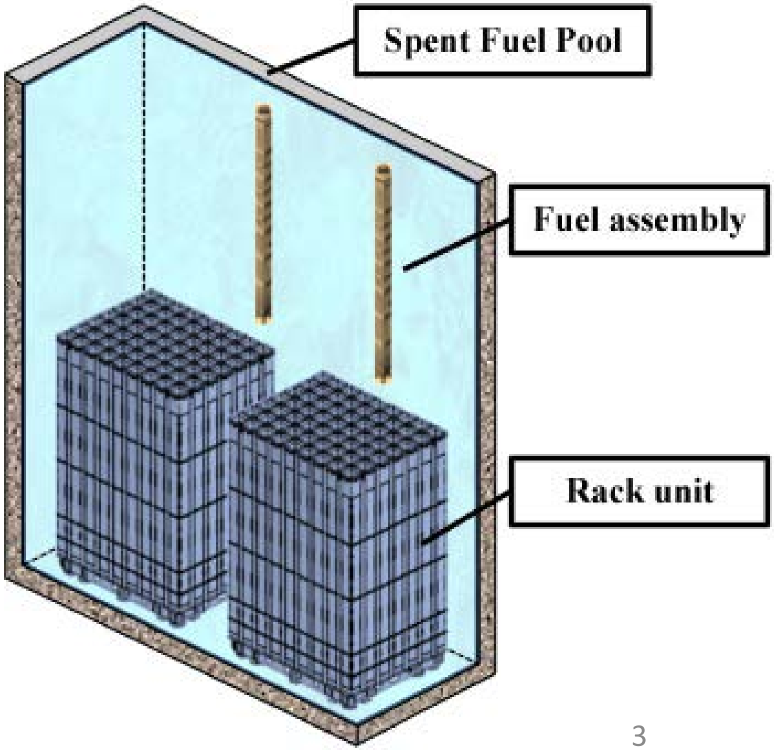
Taejin Kim*, Sangjin Lee, and Jinho Oh(KAERI)

Contents

1. Introduction

- Spent Fuel Storage Racks (SFSRs) 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.

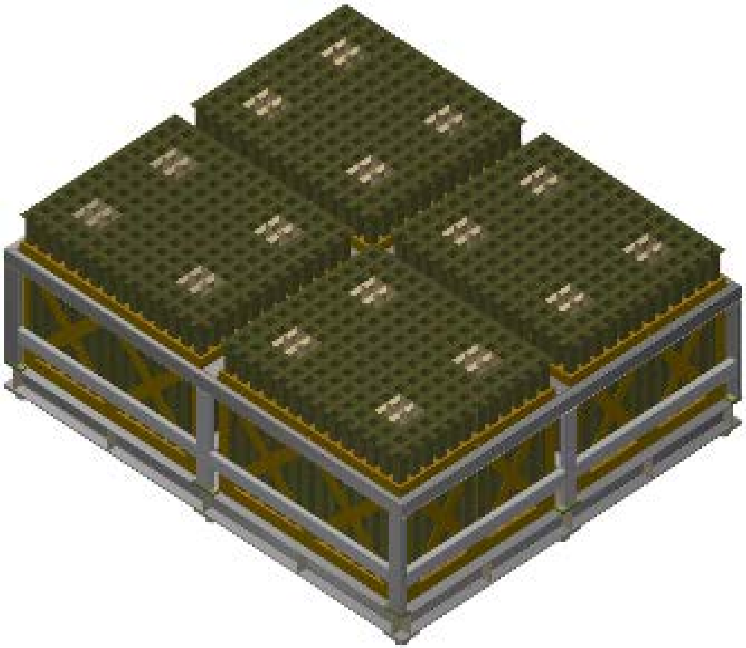


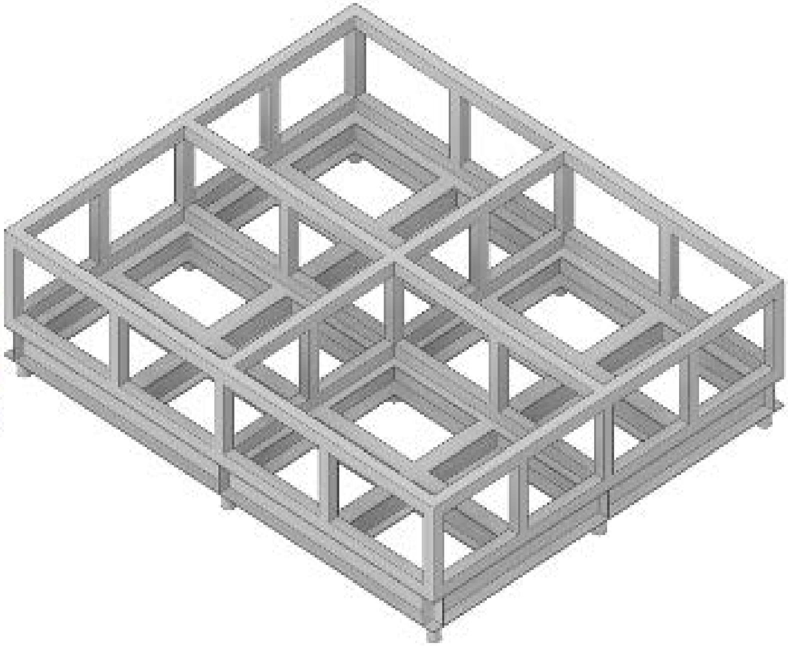


2. Analysis Model and Method

1. Analysis Model

- 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. Analysis Model and Method

2. Hydrodynamic Mass

- Fluid in the gap between fuel assemblies and cell pipes, SFSR and support frame, as well as vacancies was calculated by the representative equations.
- 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. (N/A / 10 ton / 16 ton)

$$\text{SFSR buoyancy} = W_{rack} - \frac{\rho_{rack} - \rho_{water}}{\rho_{rack}} \times W_{rack} = 922.548\text{N}$$

Where, ρ_{rack} : SFSR density = 8,027kg/m³

ρ_{water} : Fluid density = 1,000kg/m³

W_{rack} : SFSR weight in the air = 7405.295N

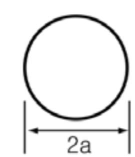
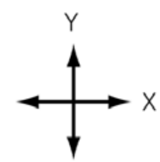
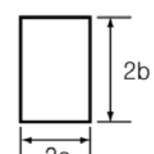
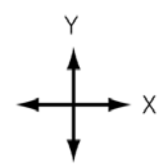
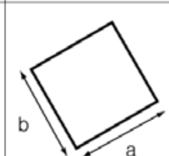
$$\text{Support Frame buoyancy} = W_{SF} - \frac{\rho_{SF} - \rho_{water}}{\rho_{SF}} \times W_{SF} = 4314.787\text{N}$$

Where, ρ_{SF} : Support frame density = 8,027kg/m³

ρ_{water} : Fluid density = 1,000kg/m³

W_{SF} : Support frame weight in the air = 34634.792N

Table 6-16. Hydrodynamic Mass in Accordance with Member Shape

Classification	Member Shape	Direction	a/b(b/a)	K	Hydrodynamic Mass (M_H)
Long Cylinder					• $M_{H_x} = \pi\rho a^2$ • $M_{H_y} = \pi\rho a^2$ • For a Unit Length
Rectangular Prism			∞	1	• $M_{H_x} = K\pi\rho b^2 L$ • $M_{H_y} = K\pi\rho a^2 L$ • L : Length
			10	1.14	
			5	1.21	
			2	1.36	
			1	1.51	
			1/2	1.70	
			1/5	1.98	
			1/10	2.23	
Rectangular Plate			b/a	K	• $M_H = K\frac{\pi\rho a^2}{4} b$
			1	0.478	
			2	0.840	
			3	1	
			∞	1	

2. Analysis Model and Method

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.
- 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.

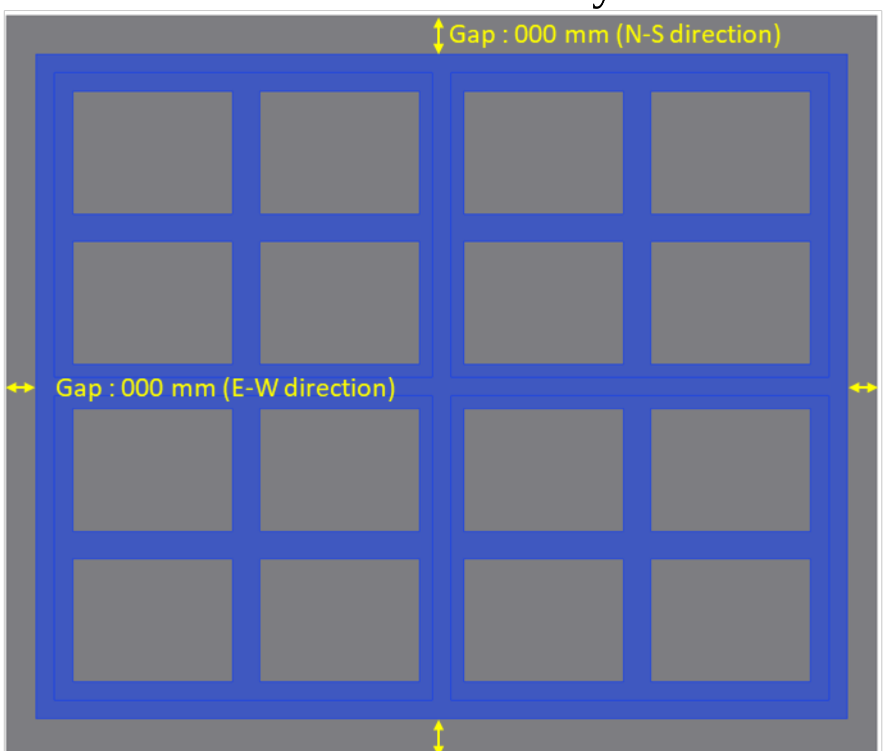
$$\mu = MU \times FACT$$

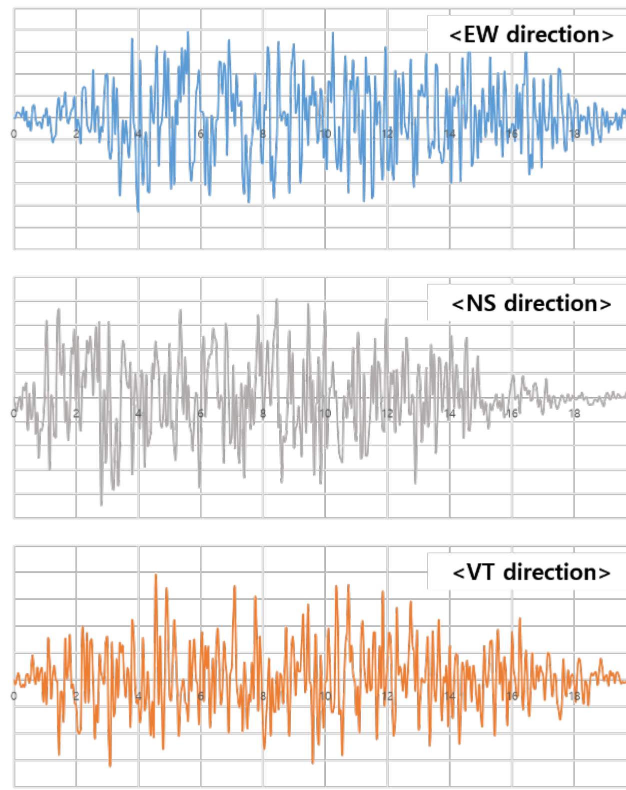
- μ : Coefficient of friction
- MU : Dynamic coefficient of friction input using the MP command
- $FACT$: ratio of static to dynamic coefficient of friction. Default value : 1.0
- Decay coefficient of Friction coefficient
- $DC = \frac{1}{V_{rel}} \times \ln(\frac{\mu - MU}{(FACT-1) \times MU})$

3. Analysis Conditions

1. Loading and Boundary Conditions

- 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.



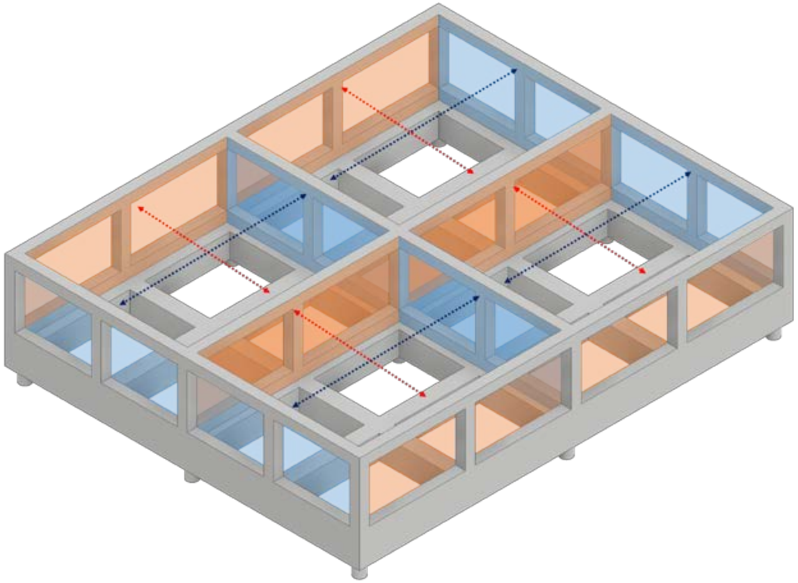


3. Analysis Conditions

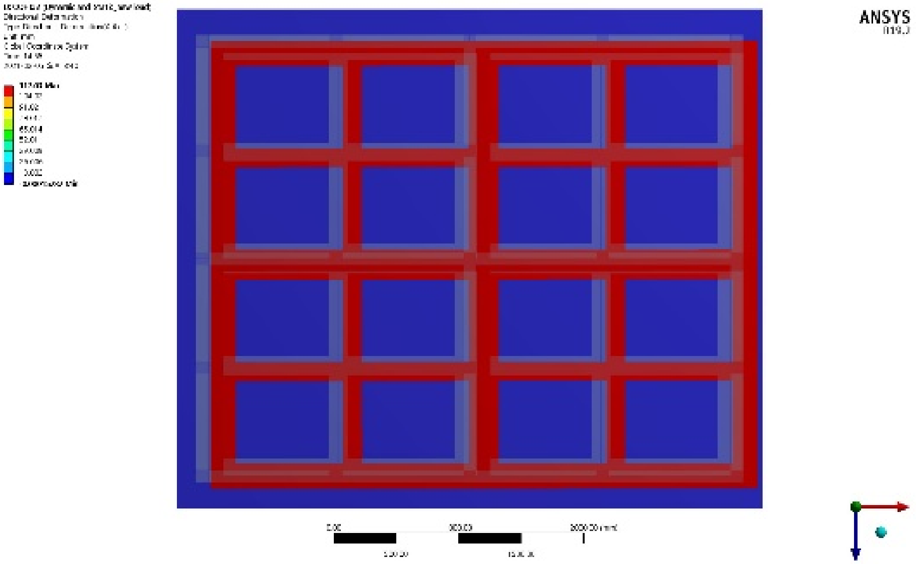
2. Analysis Cases

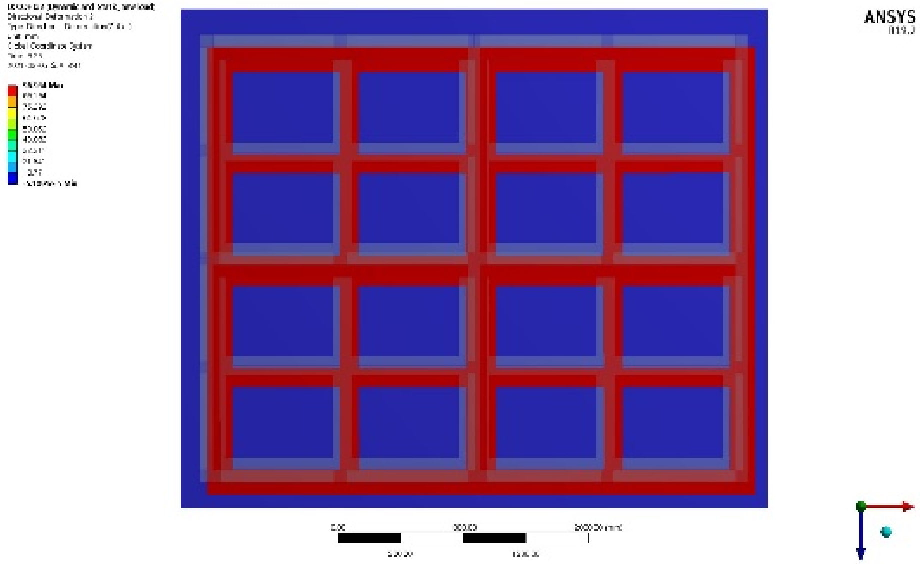
- 6 cases were selected to quantifying the hydrodynamic effects and coefficient of friction. In Cases 1-2, from a conservative point of view, hydrodynamic mass is not considered. In cases 3-4, hydrodynamic mass calculated by section 2.2 is applied. To check the dynamic mass effect with increasing the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

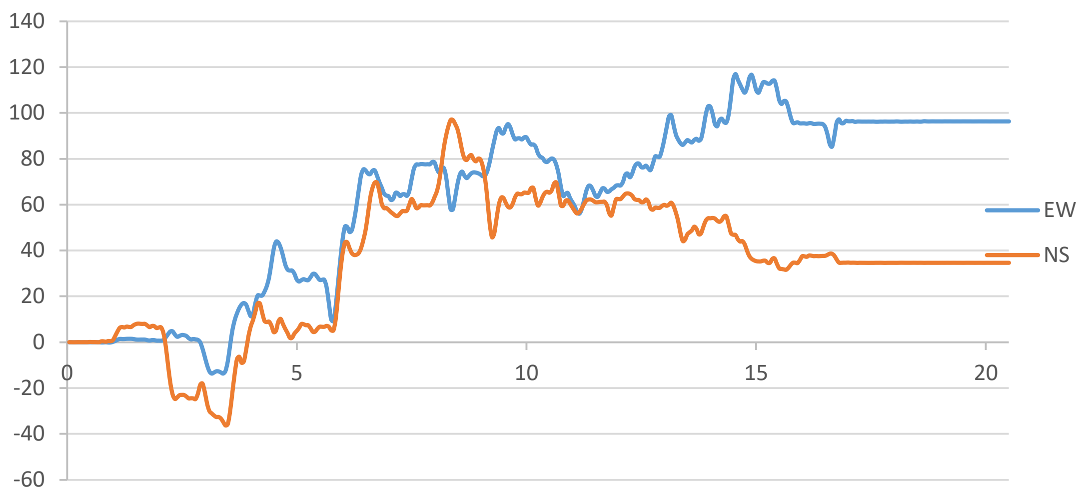
No.	Hydrodynamic mass (kg)	COF
1	N/A	0.2
2		0.8
3	10,000	0.2
4		0.8
5	16,000	0.2
6		0.8



4. Analysis Results







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

5. Conclusions

- From the seismic analyses, following results were founded
  - ✓ As the hydrodynamic mass were increased, the displacements of SFSRs were decreased.
  - ✓ 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.
- With the findings, we can conclude followings
  - ✓ 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.
  - ✓ In all cases, the friction coefficient is affected to dynamic behavior of SRSRs with increasing the friction force.

Thank you