Seismic Evaluation for a Fuel Assembly in Storage Rack of Spent Nuclear Fuel Pool

Sunghwan Chung* and Kiyoung Kim

Central Research Institute, Korea Hydro & Nuclear Power Co., Ltd., 70, Yuseong-daero 1312beon-gil, Yuseong-gu, Daejeon, Republic of Korea

*sunghchung@khnp.co.kr

1. Introduction

Storage rack of spent nuclear fuel pool (SFP rack) of nuclear power plants (NPPs) is a structure to store safely spent nuclear fuel generated from NPPs. SFP rack must be designed and evaluated in accordance with seismic category I structure classified by US NRC's RG 1.29 [1], however, SFP rack evaluation was done on SFP rack itself rather than on the fuel. US NRC suggested that the fuel in SFP rack must be maintain the integrity without damage due to seismic loads. US NRC recommended in NUREG-0800 [2] Sec. 3.8.4 Appendix D to demonstrate that the impact load on fuel to seismic excitation does not lead to damage of the fuel and to evaluate fuel deformation resulting from seismic loads does not degrade the coolable configuration of fuel. This is also issued in US NRC's design review process for APR 1400 NPP. In this study, a fuel assembly in a cell of SFP rack was modeled 3-dimensionally in detail and the behavior of fuel rods against seismic loads was analyzed. Because fuel damage refers the fuel assembly elements stressed beyond the material allowable limit such that the fuel rods were no longer able to provide confinement for radioactive materials, maximum stresses generated on the fuel rods caused by seismic loads were assessed. Relative displacements and spacing between the fuel rods of fuel assembly were analyzed to ensure the coolable configuration was maintained even if fuel rods contacted with seismic loads.

2. Seismic evaluation

Seismic analysis was carried out on one fuel assembly in the storage cell by fixing the fuel bottom to SFP rack and allowing all loads to directly act on the fuel assembly under maximum displacement conditions of the upper and lower ends of SFP rack using seismic analysis results for SFP rack (Fig. 1). Reinforced standard of 0.3g seismic acceleration was applied. Analyses were carried out using the explicit FEM program of LS-DYNA R7.1 [5]. Analysis models of one storage cell and one fuel assembly using shell, beam and solid elements are shown in Fig. 2.

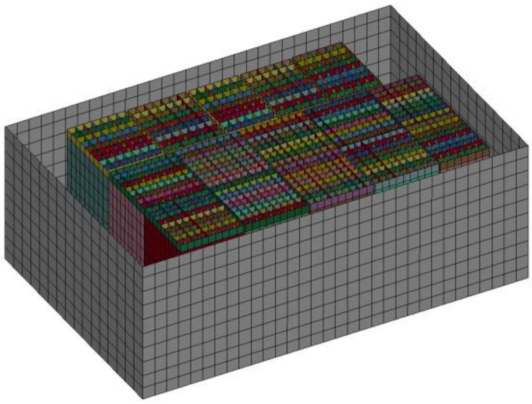

Fig. 1. Analysis model for a whole SFP rack.

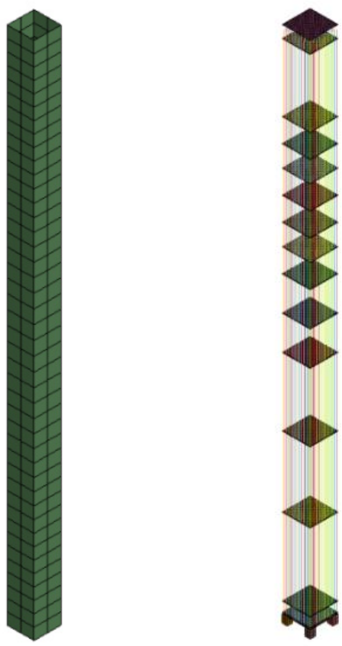

Fig. 2. Analysis models of a cell and a fuel assembly.

Maximum relative spacing and maximum stresses between the fuel rods of fuel assembly in the storage cell due to seismic loading are shown in Table 1 and 2, respectively. Spacing between the fuel rods and maximum stresses on the fuel rods were obtained by dividing the height of fuel assembly into 12 parts in East-West and North-South directions (Fig. 3). Negative values of the fuel rod spacing indicates that the fuel rods were in contact with each other and many fuel rods were contacted. There was no contact between the fuel rods at locations 8 and 9 where grid gap is narrow, but the fuel rods were in contact with each other at locations 1, 10 and 12 having a relatively large grid gap. As the fuel rod was modeled as a beam element, contact due to the thickness of fuel rod could not be considered. Stresses generated on the fuel rods were caused by the contact of fuel rods. Maximum stresses of the fuel rods were compared with the tensile strength at which at which the fuel rod is broken, but the fuel rods were not broken because all maximum stresses did not exceed the tensile strength of 651 Mpa.

Table 1. Maximum relative fuel rod spacing

Loc.	East-West (mm)		North-South (mm)	
	1-2	5-6	2-3	4-5
1	-0.46	-0.14	-0.57	-0.79
8	1.19	1.03	1.27	1.24
9	1.38	0.93	1.47	1.05
10	-0.37	-0.43	-0.54	-0.68
12	-0.74	-0.48	-0.64	-0.38

Table 2. Maximum stresses on the fuel rods

Location	Max. stress (MPa)	Tensile strength (MPa)
1	178	651
8	166	651
9	154	651
10	181	651
12	148	651

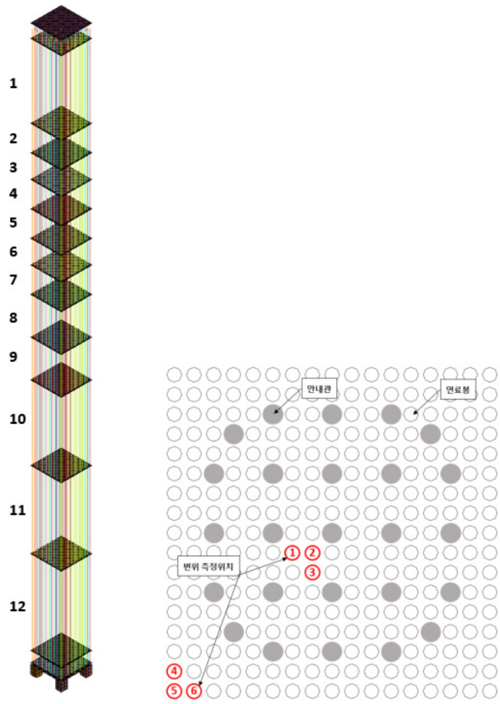

Fig. 3. Measurement locations.

3. Conclusion

It is considered that the coolable configuration of fuel assembly is difficult to be maintained because the fuel rods of fuel assembly contact each other due to seismic impact loads. However, as all maximum stresses generated on the fuel rods did not exceed the tensile strength, so that the fuel rods can be said to maintain the confinement of fuel rod. It is not easy to simulate and analyze all the fuel assemblies in the SFP rack in seismic evaluation of the fuel stored in SFP racks, so it is necessary to seek a more efficient method.

4. References

[1] US NRC, RG 1.29, Seismic Design Classification.
[2] US NRC, NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants.
[3] US NRC, RG 1.60, Design Response for Seismic Design of Nuclear Power Plants.
[4] US NRC, OT Position for Review and Acceptance of Spent Fuel Storage and Handling Applications, 1978.
[5] US LSTC, LS-DYNA Program Version 7.1, 2014.