Nonlinear Seismic Response Analysis of APR 1400 MS Line of Base-Isolated NPP

Da-Woon Yun [a*], Bub-Gyu Jeon [a], Sung-Wan Kim [a], Min-Kyu Kim [b]
[a]*Pusan National University, Busan, Korea*
[b]*Korea Atomic Energy Research Institute, Daejeon, Korea*
[*]*Corresponding author: ardw818@pusan.ac.kr*

1. Introduction

In this study, nonlinear seismic response analysis of nuclear power plant (NPP) piping systems was performed. The finite element model referring to the APR1400 MS line, which is multi-supported and arranged in a base-isolated auxiliary building and a non-isolated turbine building. The input seismic motion was used by referring to previous studies on the floor displacement response of base-isolated NPP with lead rubber bearings [1]. The damage index was calculated based on the stress-strain relationship of the elbow in the vulnerable part of the piping systems and compared with the design criteria and test results.

2. Methods and Results

Finite element analysis used the ABAQUS 6.14 program. The details of the finite element model are shown in Fig. 1. The type of element is the shell element (S4R). The seismic motions corresponding to magnitude 6.2, 6.6, 7.1, 7.5, and 7.9 were used among the 20 seismic motions in the previous study. In addition, it was defined as the floor displacement response corresponding to 100, 120, and 137.5 ft, respectively. Boundary conditions were modeled by referring to previous studies [2]. In the analysis step, the internal pressure of 6.31 MPa was pressured in Step 1, and the internal pressure was maintained in Step 2. The load was applied to the elbow in the in-plane direction to perform a nonlinear analysis.

Fig. 2 shows the results of calculating the cumulated dissipated energy and the Banon damage index as the stress-strain response to the hoop direction of elbow crown location. Banon damage index was compared with allowable stress, ASME level D service limits [3], and plastic collapse according to the size of peak ground acceleration (PGA). In previous studies, the

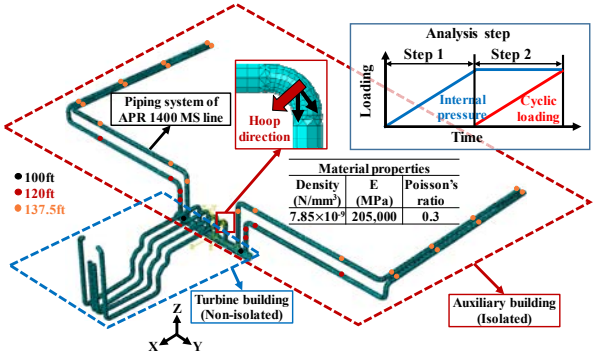

Fig. 1. Finite element model of APR1400 MS line.

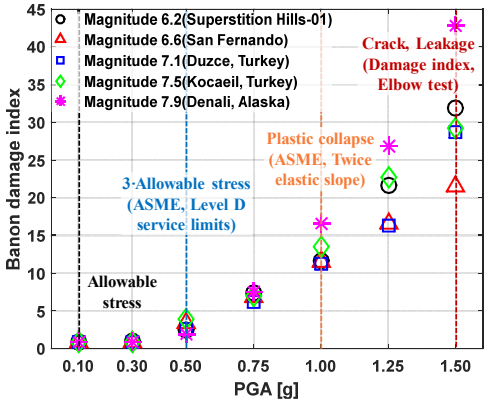

Fig. 2. Banon damage index based on finite element analysis results

Banon damage index was defined as 35.25 in case of leakage by through a crack in carbon steel pipe according to stress-strain relationship. Therefore, it could be seen that leakage by through a crack may occur at the level of 1.5g of PGA.

3. Conclusions

A nonlinear seismic response analysis was performed and the results were analyzed for the APR1400 MS line, piping systems of base-isolated NPP. When the PGA is 0.1g, the stress response is more than the allowable stress, when the PGA is 0.5g, it exceeds the ASME level D limits, and when the PGA is 1.0g, it is more than the collapse point. It was estimated that a leakage by through a crack could occur when the PGA was 1.5g. In the future, seismic performance evaluation will be performed through seismic fragility analysis.

Acknowledgment

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