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Dynamic Responses According to Seismic Analysis Procedures in Korea and Japan

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1. Introduction

Seismic analyses of the Korean Standard Nuclear Power Plant (KSNP) are performed in accordance with the domestic and the Japanese seismic design standards, respectively. The applied peak ground acceleration (PGA) of input motion is 0.4g for these analyses, and this exceeds the PGA of design input of the KSNP, 0.2g. For generating the responses at major locations of the structures, the soil-structure interaction (SSI) analyses are carried out using lumped mass stick models.

The seismic analysis based on the code requirements of Korea is performed considering linear behavior of the structure with the sub-structuring method formulated in the frequency domain. In contrast, with regard to the seismic analysis based on the Japanese standards, JEAG 4601 and JEAC 4601, the soil medium is idealized with sway-rocking (SR) springs to simulate dynamic behavior of the ground, and the superstructures are modeled to implement the flexural yielding and shear failure behavior. That is, the former method adopts using an appropriate damping ratio based on the condition of linear seismic analysis, whereas the latter directly reflects the nonlinear dynamic behavior of the soil medium and structures in the seismic analysis.

In this study, both analysis results are compared at the representative locations of the structures, and it is found that the seismic responses based on the Japanese design standards and their analysis procedures appear to be generally lower than the seismic responses based on the domestic design standards except for a few locations.

2. Seismic Analysis Models and Responses

For seismic analysis of the KSNP under beyond design-basis earthquake, the analysis models of the Reactor Containment Building (RCB) and Auxiliary Building (AB) are developed in accordance with the seismic analysis procedures of Korea and Japan, respectively. Since the KSNP has a structural characteristic that the RCB and AB are physically separated by a seismic gap, the individual analysis models are also developed for the RCB and the AB, respectively. The final models conforming to the domestic standards and their seismic analysis procedures consist of the soil medium, RCB and AB, and the SSI analysis is carried out at once by incorporating them. Through the SSI analysis using this combined model, the structure-soil-structure interaction (SSSI) effect is considered indirectly.

In the analysis model based on the seismic design standards and their analysis procedures of Japan, the RCB and AB models are developed for each direction of the structure, and the soil medium is idealized as the SR springs in accordance with the criteria in the design standards. The seismic analysis is carried out individually for the RCB and the AB, and for each direction.

Fig. 1 shows the finite element models of RCB and AB developed for the verification of the lumped mass stick models. Fig. 2 represents the lumped mass stick models for the RCB and the AB developed in accordance with the seismic design standards and their analysis procedures of Korea. In these models, the stiffness and mass properties are reflected as a single model regardless of the direction, whereas the models based on the seismic design standards and their analysis procedures of Japan are developed separately for each direction of the structures as shown in Fig. 3.

For seismic analyses, ACS SASSI is applied to the linear SSI analysis, and the RESP-F3T program that can implement the flexural yield and shear failure behavior is used for the simplified nonlinear SSI analysis.

The floor response spectra (FRS) at the dome apex of RCB are compared and shown in Fig. 4. The comparison result shows that the FRS by Japanese nonlinear SSI analysis partially exceed the FRS by domestic linear analysis. The shear strain and moment curvature levels from Japanese nonlinear SSI analysis at the wall-to-basemat junction slightly exceed the elastic range as shown in Fig. 5.

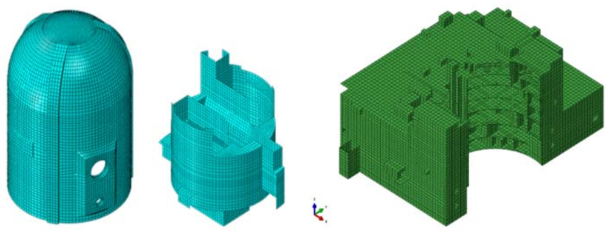


Fig. 1. Finite element models of RCB and AB

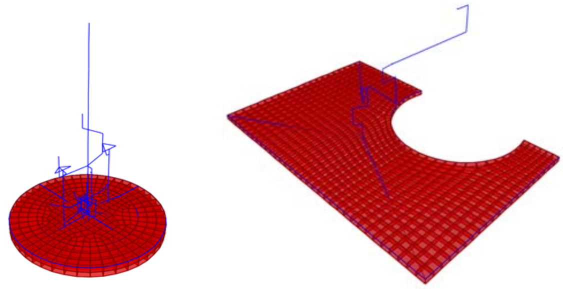
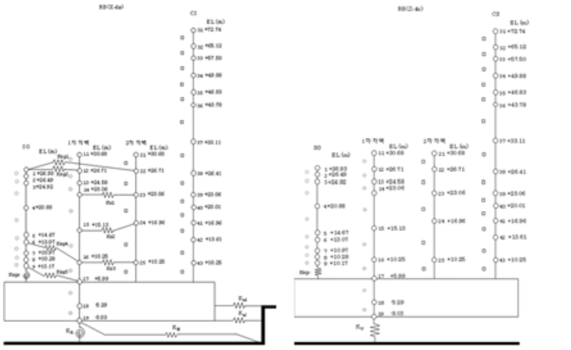
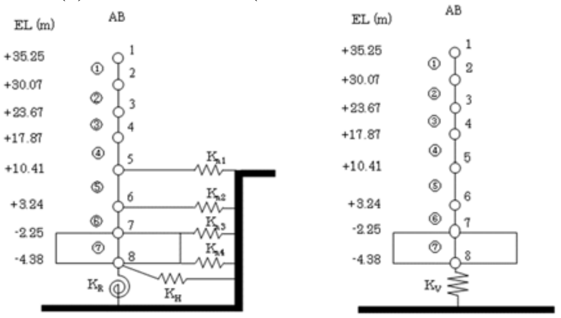


Fig. 2. Lumped mass stick models of RCB and AB

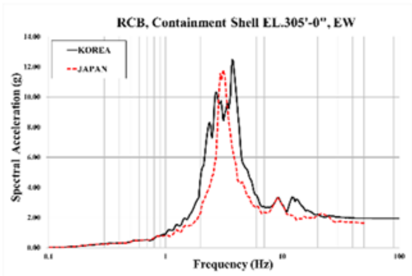


(a) RCB models (horizontal & vertical direction)

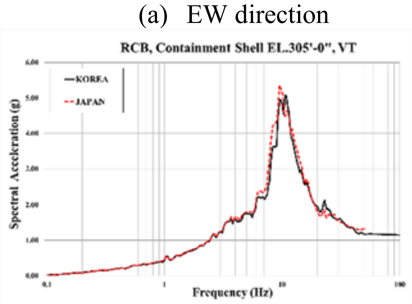


(b) AB models (horizontal & vertical direction)

Fig. 3. Lumped mass stick models of RCB and AB



(a) EW direction



(b) Vertical direction

Fig. 4. Floor responses spectra at RCB dome apex

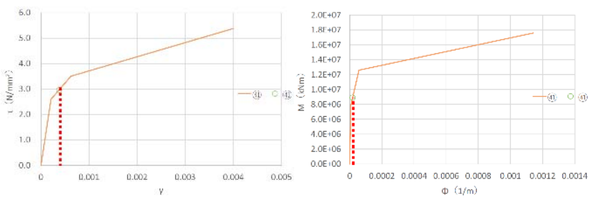
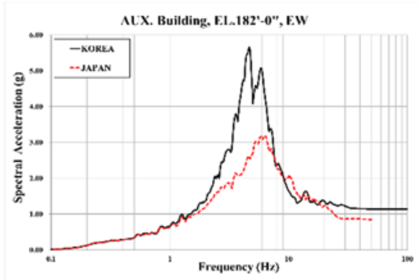
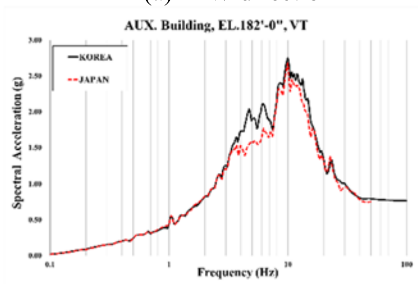


Fig. 5. Shear strain and moment curvature levels at RCB wall-to-basemat junction

Fig. 6 shows the comparison result of the FRS at the roof of the AB which is composed of shear walls and slabs. In case of a horizontal direction, the FRS by Japanese nonlinear SSI analysis are overall lower than the FRS by domestic linear analysis, and the shear strain levels at 1st floor of AB represents a nonlinear behavior of in-plane shear, whereas the moment curvature represents the state of elasticity. The FRS of a vertical direction show that there is no significant difference between both analysis results.



(a) EW direction



(a) Vertical direction

Fig. 6. Floor responses spectra at AB roof

3. Conclusions

In this study, linear and nonlinear seismic analyses of the KSNP are carried out under beyond design-basis earthquakes, 0.4g, according to the seismic design standards and analysis procedures in Korea and Japan, respectively. Comparison of the seismic responses and evaluation of the stress level of the structure are also performed. In case of the RCB, significant difference is not shown in the response and the stress and strain levels slightly exceed the elastic range. In case of the AB, the in-plane shear responses in the horizontal direction show the nonlinear behavior effect.

Acknowledgement

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REFERENCES

[1] Nuclear Standards Committee, "Technical Guidelines for Seismic Design Nuclear Power Plants (JEAG 4601)", 2015

[2] Japan Electric Association, "Technical Code for Seismic Design of Nuclear Power Plant (JEAC 4601)", 2015