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Sensitivity Study of Poisson's Ratio Used in Soil Structure Interaction (SSI) Analyses.

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1. Introduction

Korea Electric Power Corporation (KEPCO) and Korea Hydro and Nuclear Power (KHNP) began the process of seeking US Nuclear Regulatory Commission (NRC) approval for the design of Advanced Power Reactor 1400 (APR1400). The preliminary review for Design Certification (DC) of APR1400 was accepted by NRC on March 4, 2015. After the acceptance of the application for standard DC of APR1400, KHNP has responded the Request for Additional Information (RAI) raised by NRC to undertake a full design certification review. Design certification is achieved through the NRC's rulemaking process, and is founded on the staff's review of the application, which addresses the various safety issues associated with the proposed nuclear power plant design, independent of a specific site. [1]

The USNRC issued RAIs pertain to Design Control Document (DCD) Ch.3.7 "Seismic Design"[2] as follows (RAI 252-8299 Question 03.07.02-7):

- DCD Tables 3.7A-1 and 3.7A-2 show Poisson's ratios in the S1 and S2 soil profiles used for SSI analysis as great as 0.47 and 0.48 respectively. Based on staff experience, use of Poisson's ratio approaching these values may result in numerical instability of the SSI analysis results. Therefore, to assist the staff in evaluating the adequacy of the SSI analysis results based on the aforementioned soil profiles, the staff request the applicant to provide a demonstration (e.g. sensitivity study) that the assumed Poisson's ratio values do not produce numerical instabilities in the SSI results based on these profiles

The nine generic site profiles considered for design of the APR1400 standard plant, designated as S1 through S9. Figure 1 shows the low-strain shear wave velocity profiles vs. depth for the nine generic site profiles considered[3].

It is generally known that a dynamic Poisson's ratio value approaching 0.5 will cause numerical sensitivity problems in SSI analyses using the SASSI program. In the SSI analysis of the APR1400, the dynamic Poisson's ratio of the soil is limited to not greater than 0.48 in order to avoid numerical sensitivity problems. To demonstrate that the Poisson's ratio values used in the SSI analyses of S1 and S2 soil profile cases do not produce numerical instabilities in the SSI analysis results, a sensitivity study is performed using the ACS SASSI Nuclear Island (NI) model of APR1400 with S1 and S2 soil profiles.

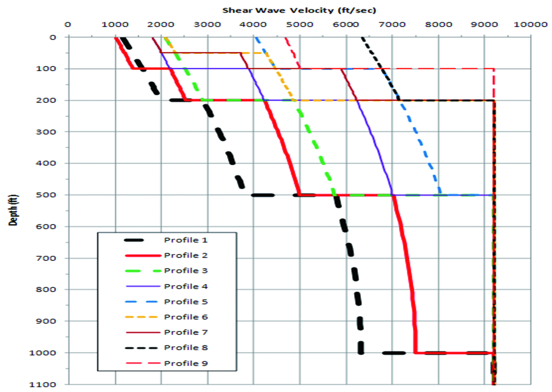

Figure 1 Generic Soil Profiles for APR1400 Standard Design

2. 2. Sensitivity Study Plan and Result

2.1 Plan

In this sensitivity study, the S1 and S2 soil profiles which have the maximum Poisson's ratio values of 0.47 and 0.48 are modified to have maximum Poisson's ratio values of 0.45 and 0.42. In the sensitivity study, the shear wave (S-wave) and compression wave (P-wave) velocities of the soil layers in the ACS SASSI NI SSI model, which have the Poisson's ratio values greater than the assumed maximum Poisson's ratio values of 0.45 and 0.42, are modified to reduce the Poisson's ratio values of the soil layers. For the horizontal SSI analyses, the compression wave velocities are modified to meet the maximum Poisson's ratio values of 0.45 and 0.42. On the other hand, for the vertical SSI analyses, the shear wave velocities of soils in the SSI models are modified to meet the maximum Poisson's ratio values of 0.45 and 0.42.

Using the modified soil profiles of S1 and S2, SSI analyses of NI models of both cracked and uncracked concrete stiffness cases are re-performed. Then, the transfer function results at NI basemat bottom and plant grade elevations obtained from the original SSI analyses and the re-performed SSI analyses in the sensitivity study are compared to judge the existence of numerical instabilities in the original SSI results. The locations of the selected nodes at basemat bottom and plant grade elevations using in the comparisons are provided in Figures 2 and 3.

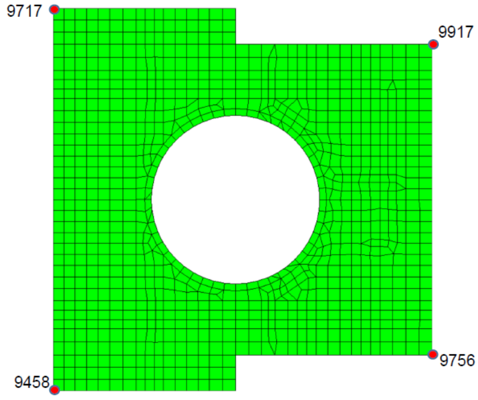

Figure 2 Selected Nodes at Basemat Bottom Elevation for Comparisons of Transfer Functions

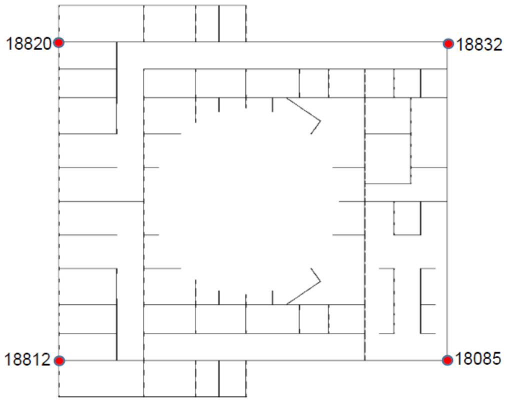

Figure 3 Selected Nodes at Plant Grade Elevation for Comparisons of Transfer Functions

2.2 Result

The comparisons of transfer function results for S1 and S2 soil profile cases are presented in Figures 4 and 5. As shown in the comparisons of transfer functions presented in these figures, the transfer functions obtained from the original SSI analyses are quite similar and comparable to the transfer functions obtained from the sensitivity study re-performed SSI analyses. In addition, no abrupt changes or spurious peaks, which tend to indicate existence of numerical sensitivities in the SASSI solutions, appear in the computed transfer functions of the original SSI analyses that have the maximum dynamic Poisson's ratio values of 0.47 and 0.48 as well as in the re-computed transfer functions that have the maximum dynamic Poisson's ratio values limited to 0.42 and 0.45. These results demonstrate that there is no numerical instabilities in the original SSI analysis results of the S1 and S2 soil profile cases.2.2.1 Base Case.

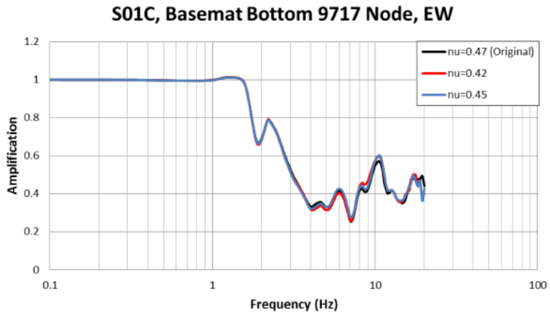

Figure 4 Comparison of Transfer Functions of 9717 Node (S1 Soil Profile, Cracked Concrete Stiffness Case)

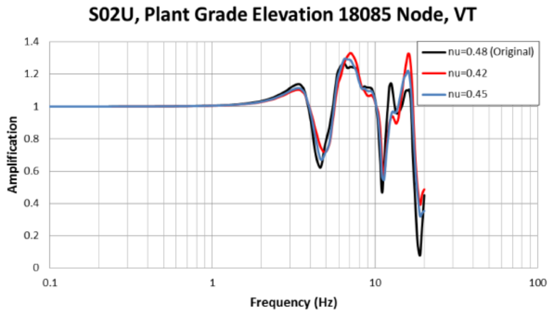

Figure 5 Comparison of Transfer Functions of 18085 Node (S2 Soil Profile, Uncracked Concrete Stiffness Case)

3. Conclusions

Sensitivity study is performed using the ACS SASSI NI model of APR1400 with S1 and S2 soil profiles to demonstrate that the Poisson's ratio values used in the SSI analyses of S1 and S2 soil profile cases do not produce numerical instabilities in the SSI analysis results.

No abrupt changes or spurious peaks, which tend to indicate existence of numerical sensitivities in the SASSI solutions, appear in the computed transfer functions of the original SSI analyses that have the maximum dynamic Poisson's ratio values of 0.47 and 0.48 as well as in the re-computed transfer functions that have the maximum dynamic Poisson's ratio values limited to 0.42 and 0.45. These results demonstrate that there is no numerical instabilities in the original SSI analysis results of the S1 and S2 soil profile cases.

REFERENCES

[1] US NRC, "Design Certification Application for New Reactors", 2015
[2] KEPCO and KHNP, APR1400-K-X-FS-14002-NP, Rev.0, "Design Control Document for the APR1400", 2014
[3] KEPCO and KHNP, APR1400-E-S-NR-14001-NP, Rev.0, "Seismic Design Bases", 2014