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Feasibility Study on a Calculation of Seismic Response Correlations Coefficient By Numerical Simulations

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1. Introduction

The seismic safety of nuclear power plants is more emphasized because the consequence of the accident is different compare with ordinary structures. Independence, diversity, and multiplicity are taken into account to design for the safety-related equipment of nuclear power plants. Nuclear power plants are equipped with various devices that perform the same safety functions in the case of a seismic accident. However, there is a failure (or seismic) correlation between structure, system, and components due to the correlation between seismic response and capacity. For this reason, the failure correlation should be taken into account when evaluating the probabilistic seismic safety assessment of nuclear power plants. The degree of correlation could represent by the correlation coefficient, and the seismic risk of the nuclear power plant changes according to the correlation coefficient. In other words, a reasonable seismic risk could be calculated by considering the appropriate correlation coefficient. In this study, it is investigated the feasibility of calculating the correlation coefficient by a numerical method.

2. Seismic correlation coefficient

The correlation between structures, systems, and components (SSCs) are correlated with seismic response and capacity, therefore the SSCs failure also has a correlation. The degree of correlation is expressed as a correlation coefficient, and in the Seismic Safety Margins Research Program (SSMRP), the following equation is proposed for the correlation coefficient [1].

$$\rho_{j,k} = \frac{\beta_{Rj}\cdot\beta_{Rk}}{\sqrt{\beta_{Rj}^2+\beta_{Sj}^2}\cdot\sqrt{\beta_{Rk}^2+\beta_{Sk}^2}}\cdot\rho_{Rj\cdot Rk} + \frac{\beta_{Sj}\cdot\beta_{Sk}}{\sqrt{\beta_{Rj}^2+\beta_{Sj}^2}\cdot\sqrt{\beta_{Rk}^2+\beta_{Sk}^2}}\cdot\rho_{Sj\cdot Sk} \quad (1)$$

Where, $\rho_{j,k}$ is correlation coefficient of plant failure, $\rho_{Rj,Rk}$ is correlation coefficient of response between unit *j* and *k*, β_{Rj},β_{Rk} are logarithmic standard deviation of response of *j* and *k*, $\rho_{Sj,Sk}$ is correlation coefficient of capacity between unit *j* and unit *k*, and β_{Sj},β_{Sk} are logarithmic standard deviation of capacity of *j* and *k*.

In order to obtain the failure correlation coefficient for SSCs, the response correlation coefficient and the capacity correlation coefficient should be calculated. In SSMRP, it is recommended to obtain the capacity correlation coefficient based on data. However, in SSMRP research, it is assumed that the correlation coefficient is zero for the capacity correlation for the research. On the other hand, the response correlation coefficient can be calculated through numerous seismic time history analyses.

3. Calculation of response correlation coefficient

The response correlation coefficient can be obtained by numerical simulation and it was performed by SSMRP and Ebisawa [2]. The methodology to obtain the response correlation coefficient is summarized as follows.

- Generating the input earthquakes with the randomness
- Generating the structures with the uncertainty
- Conducting the seismic response analyses
- Drawing the floor response spectrums
- Obtaining the response correlation coefficients

In this study, the feasibility of the response correlation coefficient calculation was investigated by Ebisawa's proposed methodology. The input earthquakes were generated considering the randomness based on the Regulatory guide 1.60 spectrum. Numerical models of an auxiliary building of the Korean standard nuclear power plant are generated considering the uncertainty. Seismic response analyses of generated input earthquakes and numerical models were performed. Floor response spectrums were generated from seismic response analysis results and the response correlation coefficients were calculated from the floor response spectrums. Figure 1 shows the response correlation coefficients at specific-location of an auxiliary building and at the ground according to natural frequencies and damping ratios of the SSCs. In figure 1, GX stands for ground and AX stands for the specific-location of an auxiliary building. Red color means high correlation coefficient, blue color means low correlation coefficient. The response correlation coefficient is different depending on the location, the natural frequency and the damping ratio of the SSCs.

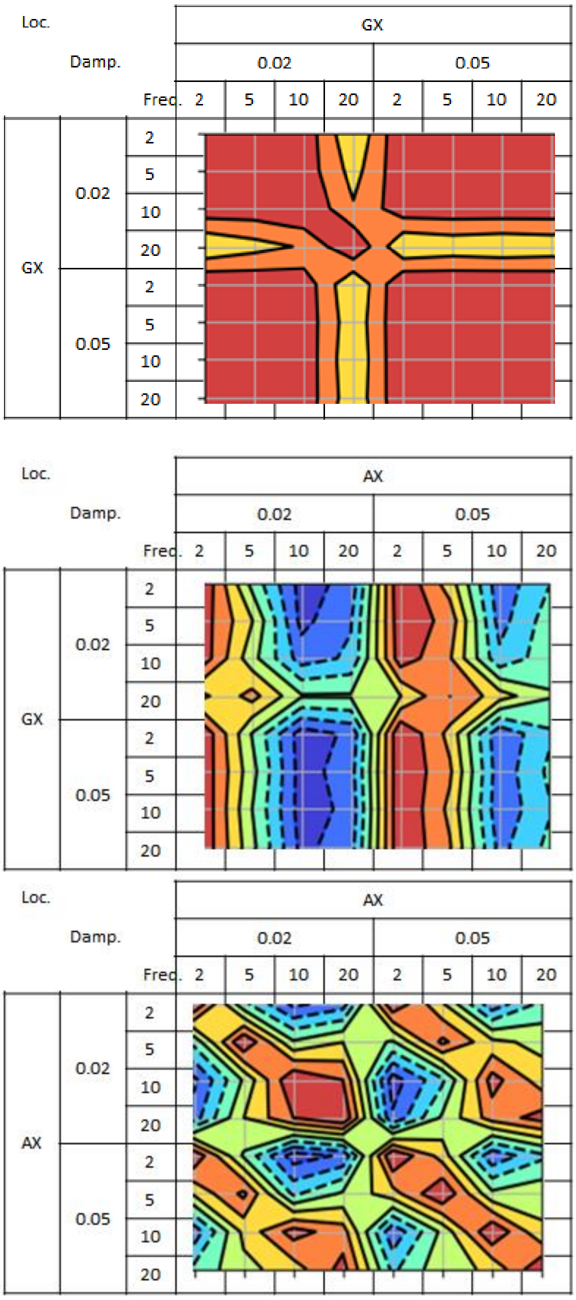

Fig. 1. Response correlation coefficient

4. Conclusion

In order to perform a rational probabilistic seismic safety assessment of nuclear power plants, the failure correlation between SSCs should be considered. A feasibility study of calculating the response correlation coefficient by numerical simulations was performed. Based on the Ebisawa's methodology, numerous input earthquakes and numerous numerical models of an auxiliary building were generated and seismic response analyses were performed. From the numerical simulation results, the response correlation coefficient at the specific location of an auxiliary building and at the ground were obtained. The response correlation coefficients between SSCs are different with positions, damping ratios, and natural frequencies of the SSCs. It is confirmed that the response correlation coefficient of a nuclear power plant can be calculated through numerous numerical simulations.

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