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Feasibility Study on a Calculation of Seismic Response Correlations Coefficient For a Nuclear Power Plant

Seung-Hyun Eem [a*], In-Kil Choi [a]

[a]*Korea Atomic Energy Research Institute, Risk and Environmental Safety Research Division, 111, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon*
[*]*Corresponding author: eemsh@kaeri.re.kr*

1. Introduction

Seismic safety of nuclear power plants is confirmed by performing probabilistic seismic safety assessment. Seismic failure correlation to structures, systems and components (SSCs) is conservatively assumed to be independent or fully dependent. Previous studies have confirmed that the one order of seismic risk values is changed by independent and fully dependent assumptions [1, 2]. This means that the calculation of the appropriate seismic failure correlation coefficients is important. The seismic failure correlation coefficient is calculated by the correlation coefficient between the seismic response and seismic performance of SSCs. The seismic response correlation coefficient can be calculated from seismic response analysis and the seismic performance correlation coefficient is derived from the data of SSCs. In this study, the seismic response correlation coefficients between SSCs are calculated for a probabilistic seismic safety assessment of Korean nuclear power plants.

2. Methods

In order to analyze the probabilistic seismic response, earthquakes and structures are generated considering uncertainties. The seismic response analyses were performed on the generated earthquake and structure, and the floor response spectrum for each main location of the auxiliary building was developed. The seismic response correlation coefficient between SSCs was calculated from the developed floor response spectrum.

2.1 Seismic Input

The nuclear power plant was designed based on the design response spectrum of Reg 1.60 [3]. Figure 2 shows the design response spectrum of Reg 1.60 (0.3g). Therefore, an acceleration time histories were generated to match with the design response spectrum (Reg 1.60) which is anchored to 0.3g. Figure 3 shows the modified acceleration hysteresis curve for the reg 1.60 design response spectrum. The 30 sets of x-direction and y-direction earthquakes were generated by assuming that the behavior of the nuclear power plant is dominated by horizontal earthquakes for the probabilistic seismic response analysis.

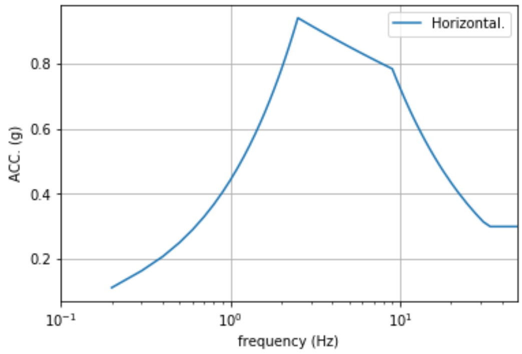
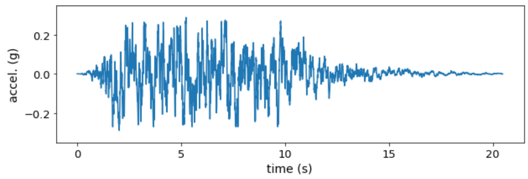
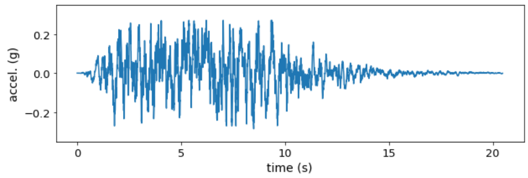


Fig. 1. Design response spectra for nuclear power plants (0.3g anchorage)



(a) x-direction earthquake



(b) y-direction earthquake

Fig. 2. One set of acceleration time history data for seismic inputs

2.2 Structural Model

The target structure is an auxiliary building of the nuclear power plant. The Auxiliary-Turbine-Access Control Building Complex is modeled due to the auxiliary building, the turbine building, and the access control building share slabs. The strength and stiffness characteristics of the structural materials which affect the seismic response of Auxiliary-Turbine-Access Control Building Complex and are used for structural modeling are represented in Table 1.

Table I: Material properties of structural model

	Strength (psi)	Modulus of Elasticity E (ksf)
Concrete	4,000	552,100

Structural Steel	50,000	4,176,000

The constructed auxiliary building model is shown in Fig 3.

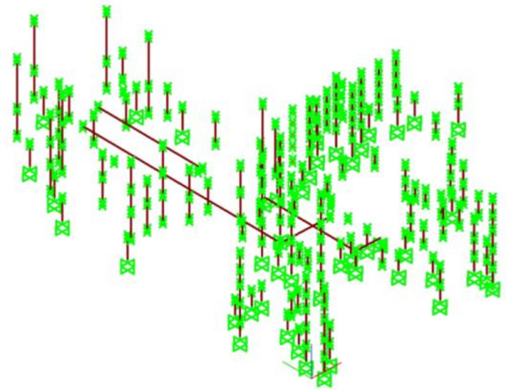


Fig. 3. Auxiliary-Turbine-Access Control Building Complex Model

2.3 Probabilistic seismic response analysis

Probabilistic seismic response analyses were performed to calculate the seismic response correlation coefficient between SSCs. Uncertainty about the directionality of the input earthquake was considered. Auxiliary-Turbine-Access Control Building Complex structures were considered for variability by applying coefficients of variation of structural stiffness and damping, which are 0.30 and 0.35, respectively [4]. From the seismic response analysis results, the floor response spectrum for the main location of the auxiliary building was developed.

3. Results and Disscussion

The seismic response correlation coefficient of SSCs can be calculated by the following equation (1).

$$\rho_{Ri,Rj} = \frac{Cov\left(X_i(a), X_j(a)\right)}{\sigma_i \sigma_j} \qquad (1)$$

where, $X_i(a)$ and $X_j(a)$ are random variables of response of SSCs i and j response. σ_i and σ_j are standard deviations of $X_i(a)$ and $X_j(a)$. Cov($X_i(a)$, $X_j(a)$) is covariance of $X_i(a)$ and $X_j(a)$.

Equipment A is located on the third floor and has a natural frequency of 5.0 Hz and a damping ratio of 3%. Equipment B is located on the second floor and has a natural frequency of 15.0 Hz and a damping ratio of 7%. The seismic response correlation coefficient for two equipment can be obtained as follows. First, the spectral acceleration of each equipment is calculated from each floor response spectrum. Then spectral acceleration distribution can be calculated as shown in figure 4. From the distribution derived from Fig. 4, the seismic response correlation coefficient can be calculated to be 0.54 by using Equation (1).

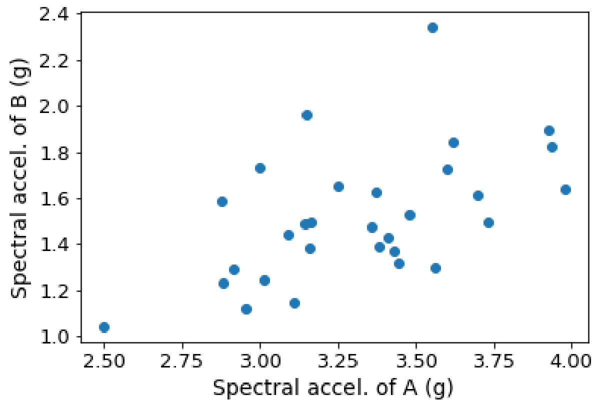


Fig. 4. Spectral acceleration distribution of equipment A and equipment B

Figure 5 shows the seismic response correlation coefficients for 5% damping ratio, 3, 15, and 25 Hz natural frequencies of SSCs for the main location of the auxiliary building.

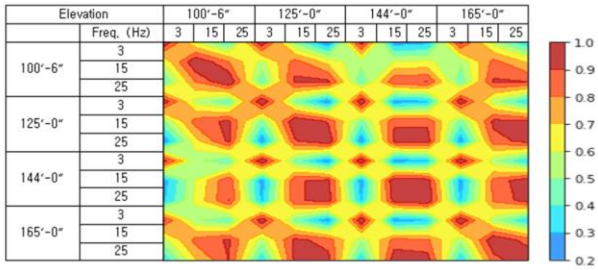


Fig. 5. Seismic response correlation coefficients for 5% damping ratio, 3, 15, and 25 Hz natural frequencies of SSCs

4. Conclusions

In order to carry out the probabilistic seismic safety assessment of nuclear power plants with the seismic failure correlation, appropriate seismic failure correlation coefficient is required. The seismic failure correlation coefficient is calculated by the seismic response correlation coefficient and seismic performance coefficient between SSCs. In this study, it is confirmed that the seismic response correlation coefficient of SSCs can be calculated by performing probabilistic seismic response analysis. In addition, the seismic response correlation coefficient for the auxiliary building was calculated for the 5% damping ratio, 3, 15 and 25Hz natural frequency of SSCs.

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