Estimation of the Correlation Coefficient for the Response Variable of the Probabilistic Seismic Fragility Curve

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1. Introduction

Seismic fragility assessment is the process of estimating the probability of failure of damage to the structures, systems and components by indicating the probability of failure to the seismic intensity. At this process, the seismic fragility curve expressed as a cumulative probability distribution is used. The formula follows the lognormal probability distribution, and variables that can be evaluated independently by separating variables are used. That is, when assessing the probability of multiple failure to two or more components, the probability of failure to each component has been assumed to be independent. However, the failure probabilities of components have seismic correlations that are related to similarities in vibration characteristics. Considering these characteristics, the probabilities of multiple failure can be calculated differently from conventional assumptions. Therefore, the probability of multiple failure must be calculated in consideration of seismic correlation to obtain realistic results. Since the basic assumption of seismic fragility is calculated by the separation of variables, correlation coefficients should also be evaluated for each variable. However, in order to assess the probability of multiple failure by considering the variation input situation of the components in the event of an actual earthquake, it is necessary to evaluate the variables by combining them at once.

2. Methods and Results

In this study, we compare the results by evaluating the correlation coefficients as the existing assumption of fragility, that is variables were individually input and all variables were combined and evaluated. In addition, depending on whether the analysis model is a detailed model or a simplified model, we conducted analysis to determine whether the correlation coefficient obtained through the simplified model can be applied to the detailed analysis model.

2.1. Models and Variables

The model was simplified from the auxiliary building of the nuclear power plant, which consisted of 6 nodes-5 degree of freedom, to a 3 nodes-2 degree of freedom model that only allows axial displacement. Target components are assumed to be two types which have the same natural frequency as the first mode (6.92 Hz) and secondary mode (17.36 Hz) of the structure model, respectively. Fig. 1 presents the mode shape and natural frequency of the two models described above, and the location of the components.

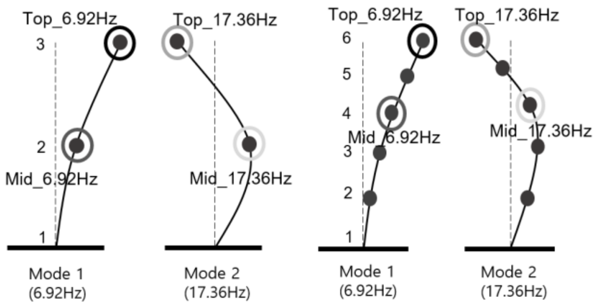

Fig. 1. Mode shape and natural frequency of simplified and detailed model and locations of components

The input seismic time history that presented on Fig. 2 was generated by stochastic method in accordance with the design response spectrum of 5% damping ratio and 0.2g peak ground acceleration specified in Reg Guide 1.60.

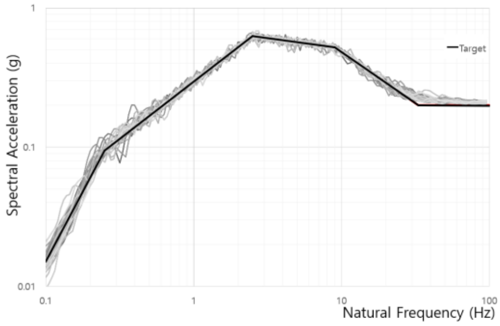

Fig. 2. Response spectra of synthesized time histories

The random variables used in the analysis, the structure damping ratio, the structure frequency, and the time history set were selected among the structure response variables suggested in the SSMRP(Seismic Safety Margins Research Program). 30 analytical cases were created by applying a normal distribution to the median and standard deviation of each variable.

2.2. Correlation Coefficients Analysis

After a time history analysis of the 30 analytical cases generated by each variable, the correlation coefficients for each corresponding location of the component and the spectral acceleration values for the natural frequency are calculated in a matrix form. In order to consider the realistic seismic correlation, 30 analysis cases were sampled by the Latin Hypercube method by combining all variables, and the correlation coefficient was calculated by the same method. In order to compare the difference of correlation coefficient between the simplified model and the detailed model, the correlation coefficient was calculated by combined variables by assuming that the same components exist at the top node of the auxiliary building of the nuclear power plant and the inflection point where the secondary mode occurs.

2.3 Correlation Results of Analysis

Table 1 presents the correlation coefficients matrix from the analysis results. The first is a correlation coefficient composed of the analysis results for each variable for a simplified model through a correlation coefficient combination formula. The next is the correlation coefficient composed of combined variables for a simplified model. And the last one is the correlation coefficient composed of combined variables for a detailed model.

3. Conclusions

Since the assumption of a fragility curve is to form a formula after evaluating by separating the variables, it is efficient to calculate the correlation coefficient for each variable as well. However, if the fragility curve is calculated by numerical analysis of structural model, it is reasonable to combine the correlation coefficient variables. Therefore, the analysis result using combined random variable input is the correct result for the model applied to the study.

We confirm that the correlation coefficient between components decreases as the model becomes more detailed. As the mode of the structure increases, the peak points of the response spectrum do not become clear, so it was determined that the response may be relatively less correlated. Although it is a more accurate result to perform correlation analysis on an analysis model, there are practical difficulties, such as having to re-calculate when the model is changed. Therefore, it may be necessary to use a simplified model to determine the approximated correlation coefficient for each for general condition.

ACKNOWLEDGEMENTS

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Table I: Components Correlation Coefficients by Combination Formula and Combined Variables of Simplified Model and Detailed Model

	Combination formula (Simplified model)				Combined variation (Simplified model)				Combined variation (Detailed model)			
Component	Top _6.92Hz	Top 17.36Hz	Mid 6.92Hz	Mid 17.36Hz	Top 6.92Hz	Top 17.36Hz	Mid 6.92Hz	Mid 17.36Hz	Top _6.92Hz	Top 17.36Hz	Mid 6.92Hz	Mid 17.36Hz
Top 6.92Hz	1	0.804	0.994	0.794	1	0.830	0.999	0.875	1	0.719	0.996	0.774
Top 17.36Hz	0.804	1	0.786	0.881		1	0.830	0.919		1	0.711	0.938
Mid 6.92Hz			1	0.795			1	0.875			1	0.788
Mid 17.36Hz	Sym.			1	Sym.			1	Sym.			1
STDEV.	-	-	-	-	0.328	0.258	0.322	0.206	0.240	0.477	0.242	0.368