A study on the procedure of determining seed motion for seismic analysis

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1. Introduction

Evaluating the seismic safety of nuclear power plants requires various seismic analyses. In order to perform site response analysis and soil-structure interaction analysis, it is necessary to generate time histories that are compatible with the target spectrum. There are two ways to generate acceleration time histories. The first is to use actually recorded seismic motions, but it is difficult to use real recorded seismic motions in Korea, where earthquake records are lacking due to the low seismicity. The second method is to artificially generate seismic motions. This method is divided into a method of mathematically synthesizing artificial seismic motions and a method of modifying recorded seismic motions. In the conventional approach, synthetic seismic motions were also widely used, but it is known that synthetic seismic motions do not reflect the non-stationary characteristics of real earthquake motions. And recently, the method of modifying measured seismic motions has been recommended. In this process, the actual recorded seismic motions used for correction are called "seed motion".

Seed motion is more important in nonlinear than linear analysis because it determines the fundamental properties of the spectral-compatible acceleration time history. For example, if the seed motion contains strong pulses, it is likely that pulse-shaped oscillations will appear in the spectrum-compatible acceleration time history as well. Conversely, if there are no pulses in the seed motion, very few pulses will appear in the spectral-compatible acceleration time history. Seed motions thus affects the nonlinear response of the spectral compatible acceleration time history. In Korea, there are cases of selecting seed motion in various studies, but the cases presented for specific procedures are insufficient. In this study, the criteria to be considered in determining seed motion for seismic analysis are analyzed, and detailed processes are also suggested.

2. Criteria for Seed Motions in Standards

In general, the characteristics of seismic motions can be divided into three categories. The first is the intensity of the seismic motions, which can be defined as the peak ground acceleration, velocity, and displacement (PGA, PGV, PGD). It can increase as the earthquake's magnitude rises and the epicenter distance becomes closer. The second is the frequency characteristic, which can be confirmed through the shape of the response spectrum and the power spectrum density function. It is known that the larger the earthquake magnitude, the stronger the low-frequency characteristic. The third is the duration of the seismic motions, which can be defined as the time of the entire seismic motion or the duration of the primary vibration (strong earthquake duration). Most standards stipulate that the various characteristics of the seismic motions mentioned above should be similar to the conditions of the target site and the target spectrum when selecting the seed motion.

SRP 3.7.1 states that if the design ground motion time history is intended to be compatible to a site-specific foundation input response spectrum, it should have characteristics consistent with characteristic values for the magnitude and distance of the appropriate controlling events defined for the corresponding uniform hazard response spectrum [1]. ASCE 43-05 states that if modified recorded time histories are generated to match the target spectrum, it is important to ensure that the phase spectra of the motions are generated from recorded motions in the appropriate magnitude-distance bins. In addition, the strong motion duration shall fall within the range appropriate for the magnitude-distance bin [2]. ASCE 4-16 states that resulting ground motion histories shall have characteristics that reasonably represent the input motion expected for the location, e.g., have PGA, PGV, PGD and duration appropriate for the magnitude and distance of the primary events contributing to the seismic hazard [3].

3. Procedure of determining seed motion

In this section, the procedure of determining seed motion for seismic analysis was suggested, which includes selecting seismic records and matching them to a target spectrum. This is not a new concept, but it is a comprehensive arrangement of the order based on the previously organized contents. The suggested procedure consists of ten steps.

First, the target spectrum for seismic analysis should be determined, such as the site-specific ground motion response spectrum derived through the probabilistic seismic hazard assessment. And for effective seed motion selection, a database should be established by collecting many earthquake records. In the case of Korea, since strong earthquake records are lacking, it is judged that the Pacific Earthquake Engineering Research Center database, which contains the strong motion record in the US, can be utilized. And it is necessary to determine the main controlling earthquake scenarios for primary contributing to the seismic hazard at the site. This can be obtained through the deaggregation of the probabilistic seismic hazard assessment results. Choi et al.(dd)

conducted a study to determine the controlling earthquakes in Korea. An earthquake of about magnitude 6.2 and an earthquake distance of 13.0 km has been derived as major earthquake scenario [4].

The following is the process of selecting seed motion according to the controlling earthquake scenario. The selection criteria were classified into five categories, and the order was placed in consideration of the efficiency of the selection process. First, earthquake records that do not meet the criteria are excluded by considering the duration of the earthquake and the correlation coefficient for directional components. Then, seismic motions are selected based on the controlling earthquake scenario. If the number of selected seismic motions is greater than the target number, the target number is selected based on the degree of similarity in spectral shape with the target spectrum, earthquake events, and other earthquake characteristics. And matching the target spectrum is performed using seed motion, and finally, the generated artificial earthquake time histories are reviewed to confirm the validity of the seed motion selection based on the related criteria. SRP 3.7.1 presents some requirements for time histories for dynamic structural analysis, time interval and spectrum comparison criteria.

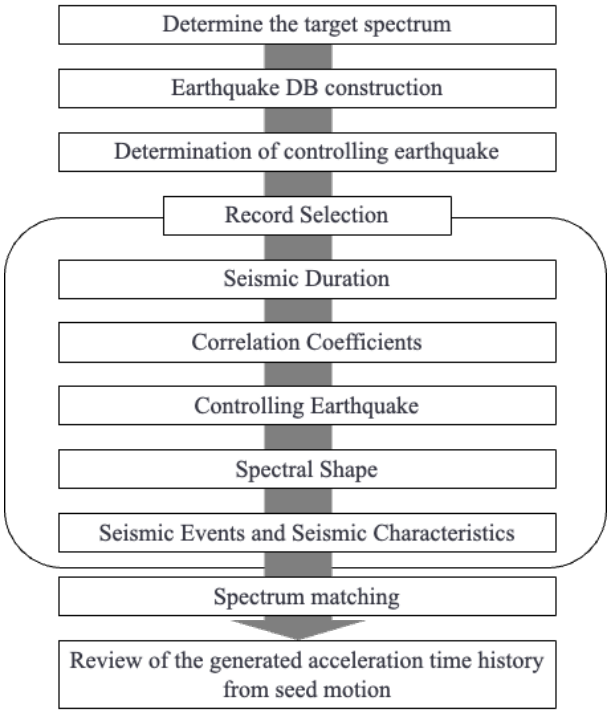

Fig. 1. Suggested procedure of determining seed motions

4. Conclusions

Seed motion is used when generating time histories that match the target spectrum when performing seismic analysis of nuclear structures and is an important factor that can significantly affect the results in nonlinear analysis. This study analyzed the requirements required by the current standards for determining seed motion. And based on various conditions, a procedure for determining the seed motion was suggested. The proposed process includes determining the target spectrum and the controlling earthquake scenario, selecting seismic records based on seismic duration, correlation coefficients, earthquake scenarios, and spectral shape, and matching the final selected seed motion to the target spectrum. This procedure is expected to be used for earthquake analysis of nuclear structures in the future, and it is planned to be continuously supplemented by applying domestic cases.

Acknowledgement

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