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Analysis of variability in foundation seismic responses by unit at the multi-unit NPP sites using recorded earthquake data.

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1. Introduction

Most nuclear power plants in the world are multi-unit sites containing more than one unit. Although an accident coinciding in multiple units has a very low probability, its consequences are very severe. After the Fukushima nuclear power plant accident in 2011, interest in multi-unit Probabilistic Safety Assessment (PSA) has increased, and related research and standards are being developed [1, 2].

Earthquake is natural disasters with widespread impact and is one of the major external events considered in the PSA. The seismic safety of structures and equipment expressed in seismic fragility can be defined as the ratio of the input earthquake load and the capacity of the elements [3]. Therefore, it is essential to accurately determine the seismic input load to the foundation of the structure. However, the response at the foundation level is not the same even for the same reactor located at the same site, and detailed studies on this variability are still lacking.

This study analyzed the variability of the foundation response between units in a multi-unit nuclear power plant site based on the recorded responses of nuclear power plants in Japan. The peak ground acceleration and response spectrum of the foundations in five multiple nuclear power plants were compared.

2. Recorded Earthquake Data

In Japan, earthquake monitoring systems for nuclear power plants are in operation, and some data are provided through the Japan Association for Earthquake Engineering (JAEE) [4]. In this study, the provided data was purchased and utilized for analysis.

The response variability of the foundation during earthquakes was investigated for a total of five nuclear power plants. Table 1 shows the brief information for the nuclear power plant and the recorded earthquake used in this analysis. All plants are multi-unit sites with four or more units. The location of each power plant and earthquake is depicted in Fig. 1 by varying the marker size according to the number of units and the earthquake's magnitude. For the Kashiwazaki-Kariwa nuclear power plant, the two markers was overlaped because the epicentral distance is short within 20 km.

Table I: Information for Nuclear Power Plants and Recorded Earthquakes used in Analysis

NPP	Units[1)]	Earthquake	Date	M[2)]
Onagawa	6	Miyagiken-Oki	2005.08.16	7.2
Kashiwazaki -Kariwa	7	Niigata-Chuetsu	2007.07.16	6.8
Hamaoka	5	Suruga Bay	2009.08.11	6.5
Fukushima Daiichi	6	Tohoku	2011.03.11	9
Fukushima Daini	4	Tohoku	2011.03.11	9

1) Number of Units at Nuclear Power Plant Site
2) Earthquake Magnitude

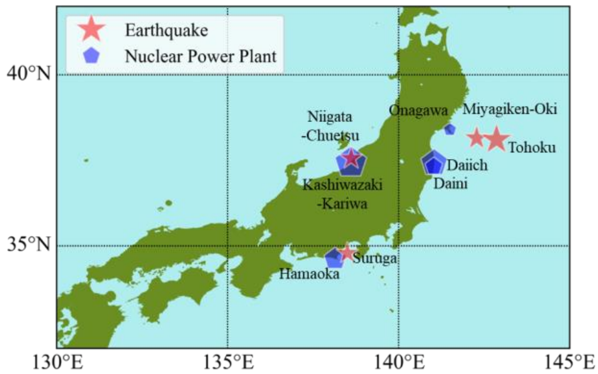

Fig. 1. Locations for Nuclear Power Plants and Recorded Earthquakes used in Analysis

3. Seismic Response Variability for Foundation of Reactor Building (RB)

3.1 Peak Ground Acceleration

Fig. 2 shows the peak ground acceleration for each unit's east-west direction acceleration measurements on the foundation of the reactor building (RB). Star markers indicate the mean values of each plant. The larger peak ground accelerations were observed at the Kashiwazaki-Kariwa and Fukushima Daiichi nuclear power plants due to the short epicenter distance and large earthquake magnitude. The variability between units also increased as the mean peak ground acceleration increased, and the maximum difference from the average value was about

0.2g. This difference value is difficult to ignore in the PSA compared to the safe shutdown earthquake criterion of 0.2 for OPR 1000.

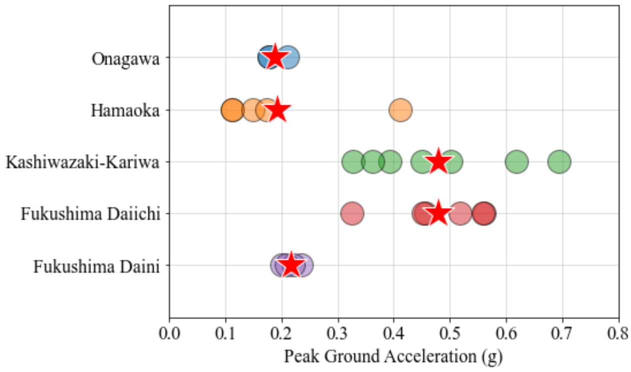

Fig. 2. Peak Ground Acceleration Variability of Foundation Response by Units

3.2 Response Spectrum

Fig.3 and Fig.4 compare the acceleration response spectrum of the reactor building foundation of the Kashiwazaki-Kariwa and Fukushima Daiichi nuclear power plants. There was a significant difference in the spectral acceleration values for each unit over all frequencies. In particular, the difference was conspicuous at the dominant frequency, where the spectral acceleration was the largest. The maximum difference was greater than 0.7g in both nuclear power plants. These variabilities of the foundation response can be caused by several factors such as the wave propagation, depth of the foundation, and specific soil conditions. However, as the spectrum data shows a very random trend by unit, it is difficult to find the specific reason, and additional analysis is necessary.

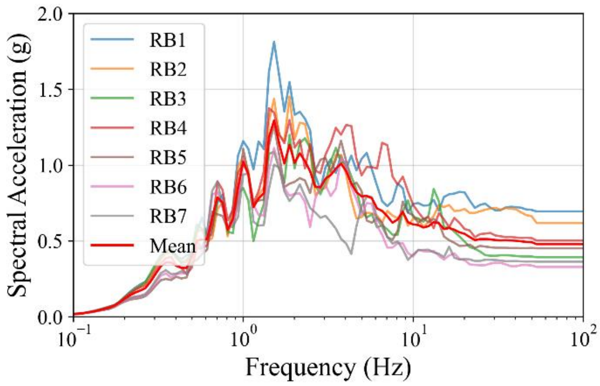

Fig. 3. Response Spectrum of Foundation Response at Kashiwazaki-Kariwa Nuclear Power Plants

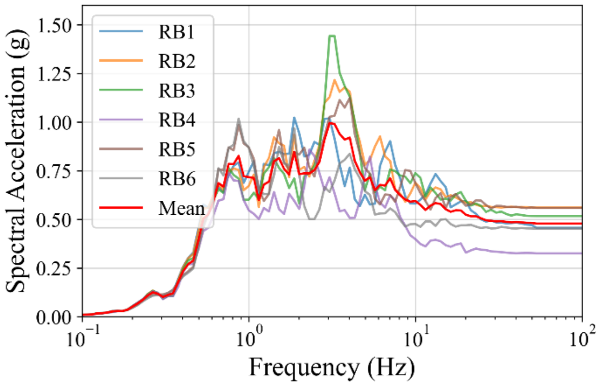

Fig. 4. Response Spectrum of Foundation Response at Fukushima Daiichi Nuclear Power Plants

4. Conclusions

In this study, the variability of the foundation response for each unit in the multi-unit nuclear power plant was evaluated using the earthquake records measured at the five plants in Japan. The peak ground acceleration showed a difference of more than 0.2g, and the spectral acceleration value according to frequency also showed a difference of more than 0.7g for each unit. These variabilities note that it is necessary to appropriately consider it in the seismic PSA of multi-units in the future after more detailed review and assessments.

Acknowledgement

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