Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2017

Seismic Fragility Reevaluation of SSCs in NPP with Site-specific Response Spectrum

In-Kil Choi [a*], Junghan Kim [a], Jinhee Park [a], Minkyu Kim [a], Jaeho Jeon [b]
[a] *Korea Atomic Energy Research Institute, Daejeon, Korea*
[b] *JACE Korea, Seongnam, Kyeongki, Korea*
[*] *Corresponding author: cik@kaeri.re.kr*

1. Introduction

Gyeongju earthquake, M 5.8, occurred in last year is the large earthquake occurred in Korea since the earthquake observation started. Due to this earthquake, an earthquake safety of the operating nuclear power plants near the earthquake epicenter became hot issue. The recorded earthquake ground motion shows the typical characteristics of a high frequency ground motion which is different from that of the design earthquake. In this study, the effect of ground motion characteristics, frequency contents of earthquake ground motion, on the seismic fragility of components in a nuclear power plant building was estimated.

2. Development of Reference Response Spectrum

Gyeongju earthquake shows typical characteristics of high frequency ground motion. The frequency content of the Gyeongju earthquake is very similar to that of a typical CEUS (Central and Eastern United States) site earthquake ground motion. Fig. 1 shows the response spectra of earthquake ground motions observed at USN site where is located near from the epicenter. As shown in this figure, the high frequency contents of the Gyeongju earthquake is very rich compare to the design earthquake, US NRC R.G. 1.60 spectrum [1].

This figure also shows the normalized acceleration response spectra of the earthquake records observed at Gyeongsang Basin. Those earthquakes are M3 to M5 occurred in 1990s

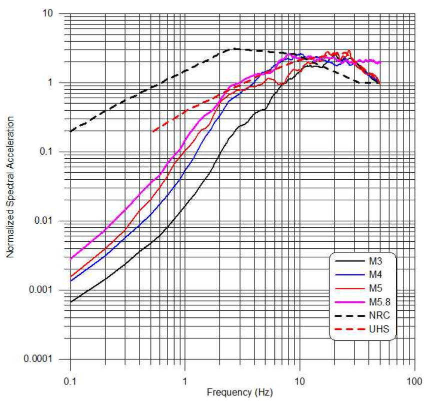
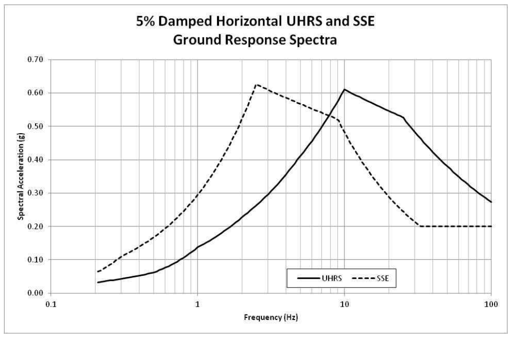
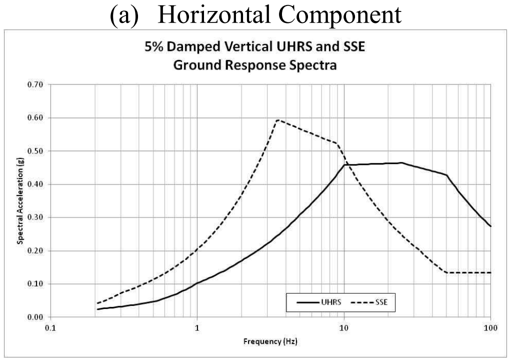


Fig. 1. Normalized Acceleration Response Spectra of Gyeongju Earthquake.

To estimate the effect of the characteristic of Gyeongju earthquake on the seismic response and safety of a nuclear power plant SSCs, the reference earthquake response spectrum for a seismic fragility analysis was developed from the probabilistic seismic hazard analysis. The UHRS (Uniform Hazard Response Spectrum) for the Ulchin site was developed. Fig. 2 shows the developed UHRS for Ulchin site with a design response spectrum.



(a) Horizontal Component



(b) Vertical Component

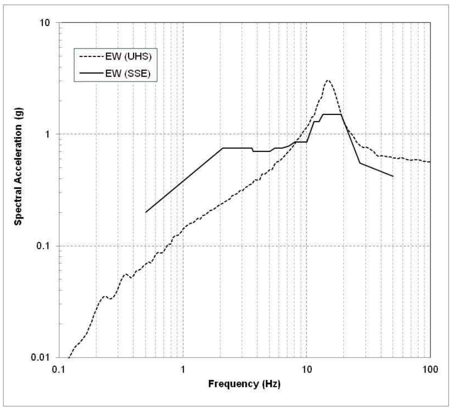
Fig. 2. Comparison of Reference Input Response Spectrum for Seismic Fragility Analysis with Design Earthquake.

3. Generation of Floor Response Spectra

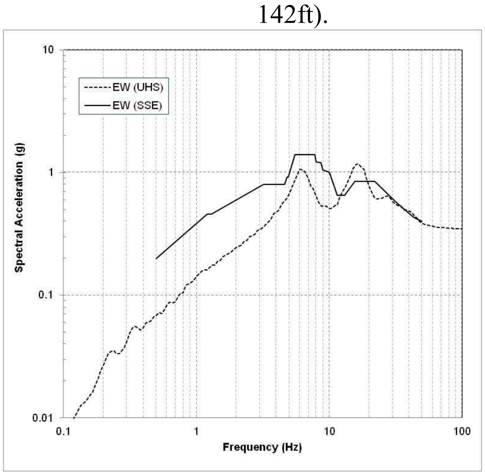
In general, the difference of spectral acceleration between the design earthquake and reference earthquake is considered as a spectrum shape factor, which is the spectral acceleration ratio at the natural frequency of the SSCs. The floor response spectrum is used as a required response spectrum for the seismic qualification and seismic fragility analysis of ae equipment installed in a building.

The floor response spectra can be obtained by the scaling of a floor response spectra from SSE (Safe Shutdown Earthquake) analysis or reanalysis by using the reference earthquake input motion. The use of different shape ground response spectrum may result in significant variations in the shapes of the floor response spectra. The scaling of the floor response spectrum can be used when the shape of the reference response spectrum is similar to that of the SSE response spectrum. This method is considered acceptable for rock sites provided the overall shapes of the SSE and reference response spectrum are similar [2,3].

The UHRS shape is quite different of the SSE response spectrum. The scaling method can't be used for the generation of floor response spectra for the UHRS. In this study, the reanalysis was performed to generate the floor response spectra by using existing structural analysis model. Fig. 3 show the comparison of the floor response spectrum at the containment building and primary auxiliary building. As shown in these figures, the shape and the amplitude and frequency at the peak spectral acceleration are different. The amplitude at high frequency range of the generated floor response spectra is higher than that from SSE analysis.



(a) Containment Building at Operating Floor (EL. 142ft).



(b) Primary Auxiliary Building (El. 100ft).

Fig. 3. Comparison of Floor Response Spectrum According to the Reference Input Earthquakes.

4. Seismic Fragility Analysis

The seismic fragility analysis was performed for the equipment in the same floor with different fundamental frequency. The location of those equipment is EL. 100ft of the primary auxiliary building. And the fundamental frequency of the equipment is 8 Hz and 18.7 Hz, respectively. Table I shows the seismic fragility analysis results for the equipment. As shown in this table, the frequency contents of the input ground motion may affect the seismic margin of the equipment installed in a building. An equipment shows greater margin for UHRS, and another equipment shows less margin for UHRS comparing with that for SSE.

Table I: Comparison of Fragility Parameters of Two Equipment Which have Different Dynamic Characteristics Located PAB 100ft.

Equip.	Natural Freq. (Hz)	Failure Mode	UHRS		SSE
Class 1E DC Motor Control Center	8	Welding Failure	A_m	1.92	0.83
			β_r	0.24	0.31
			β_u	0.28	0.28
			HCLPF	0.82	0.31
		Functional Failure (During Earthquake)	A_m	2.12	0.55
			β_r	0.25	0.31
			β_u	0.43	0.24
			HCLPF	0.70	0.22
Diesel Generator Room HVAC Control Panel	18.7	Frame Bending Failure	A_m	1.62	S/O
			β_r	0.23	
			β_u	0.28	
			HCLPF	0.70	
		Functional Failure (During Earthquake)	A_m	2.11	S/O
			β_r	0.25	
			β_u	0.34	
			HCLPF	0.80	

5. Conclusions

In this study, the effect of the frequency contents of the input ground motion was estimated. The high frequency ground motion which is a typical characteristics of earthquake occurred in Korea should be considered in the seismic fragility analysis of an equipment installed either in a building or on the ground.

To generate the floor response spectra for an input motion which has different spectral shape compare to the design earthquake, reanalysis is better than the scaling method.

Acknowledgment

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIP) (No. 2017M2A8A4014825)

REFERENCES

[1] NRC, Design response spectra for seismic design of nuclear power plants, Regulatory Guide 1.60, 2014.

[2] Reed, J. W., and R. P. Kennedy, Methodology for Developing Seismic Fragilities, EPRI TR-103959, 1994.

[3] Reed, J. W., R. P. Kennedy, D. R. Buttemer, I. M. Idriss, D. P. Moore, T. Barr, K. D. Wooten, and J. E. Smith, A Methodology for Assessment of Nuclear Power Plant Seismic Margin (Revision 1), EPRI NP-6041-SL, 1991.