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

Development of Korean Standard Design Response Spectrum

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1. Introduction

For the seismic design of conventional facilities in Kores, design response spectra developed in other countries has been used. There is a need to develop Korean specific design response spectrum because the earthquake environment of Korea is much different to other high seismicity regions. Korea is known to belong to an intra-plate region and the spectrum shape of intra-plate earthquakes are expected to have strong high frequency content rather than the spectrum of inter-plate earthquakes. For this reason, the Korean standard design response spectrum was developed recently. This paper introduces the development method and the spectrum shape as a result.

2. Response Spectrum of Recorded Ground Motions

2.1 Database of Intra-Plate Earthquake Ground Motion

The ground motions used in developing response spectrum is 55 recorded accelerograms of 18 earthquakes. These earthquakes occurred at intra-plate regions. The closest distances from site to the fault, or hypocentral distances are less then 200km. Among the ground motions, domestic ground motions recorded in Korea are 24 accelerograms of 5 earthquakes [1]. All record was observed at rock sites.

2.2 Spectral Acceleration

The design response spectrum is the graph of spectral acceleration with regard to natural frequency or natural period of a single degree of freedom system. Therefore, the spectral acceleration of each period need to be calculated using a ground motion time history. However, the horizontal ground motion is two-dimensional movement. So, two horizontal spectral acceleration is obtained in a set of record and the representative value should be determined.

For this, the geometric mean spectral acceleration value was calculated. The GMRotI50 is one of the definition of geometric mean of two horizontal spectral acceleration, which is independent of natural period of the single degree of freedom system [2].

2.3 Statistical Analysis

The response spectra obtained by recorded ground motion was depicted in Fig. 1. Its mean spectrum and mean+1σ spectrum are also represented in this figure. For the conservatism of design mean+1σ spectrum was used for constructing the design response spectrum.

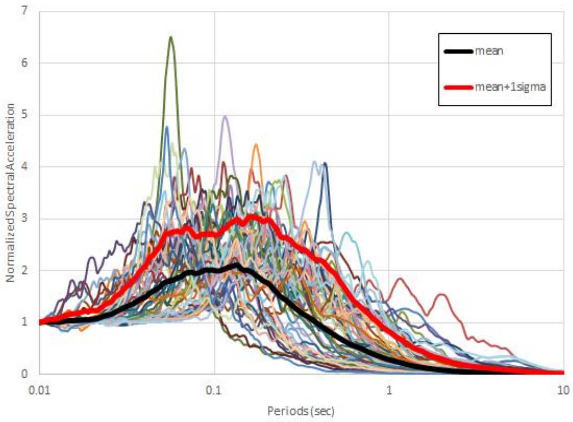

Fig. 1. Response Spectra of Recorded Ground Motions and its Mean and Mean+1σ Spectrum.

3. Construction of Response Spectrum Shape

2.1 Piecewise Linear Function

The statistical value of each spectral accelerations used to be fluctuate in period by period. However, the shape of design response spectrum should have simple expression by smoothed line. Here, the piecewise linear function in a log-normal scale was adopted.

The response spectrum usually have three intervals, which is acceleration, velocity and displacement sensitivity ranges. In the acceleration sensitivity range, the spectral acceleration used to be constant. The velocity sensitivity range and the displacement sensitivity range decay by $1/T$ and $1/T^2$, respectively. From the zero period to the start of acceleration sensitivity range is linear in log-normal scale. Between these ranges, the intersecting points are determined. This can be defined as transition periods.

The piecewise linear function was estimated coincident to the mean+1σ normalized spectrum of recorded data. As a result, the short period amplification factor which is the ratio of acceleration sensitive range value to zero period value, and three transition periods were estimated as Table I. Using these parameters, the design response spectrum can be constructed. Fig. 1

shows the mean+1σ spectrum and its piecewise linear spectrum applied by the determined parameters. Detailed procedure was described in the original paper [3].

Table I: Spectrum Parameters

Short Period Amplification Factor	Transition Period (second)		
	T_O	T_S	T_L
2.8	0.06	0.3	3.0

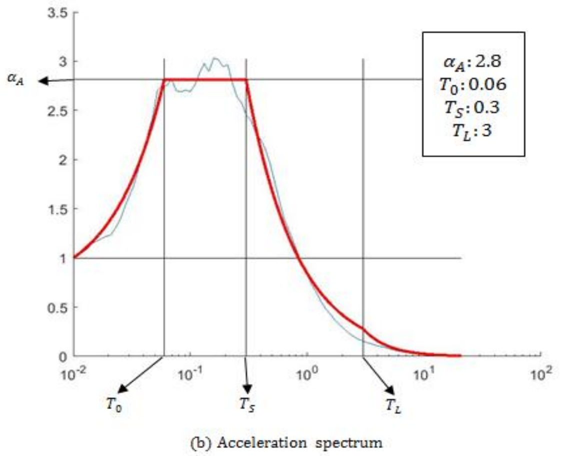

Fig. 2. Mean+1σ Spectrum and Its Piecewise Linear Spectrum

2.2 Comparison with other Spectrum

To compare the spectrum shape of developed design spectrum, several design spectra in other codes were drawn in Fig 3. These spectra is normalized by zero period spectral acceleration value. The developed spectrum has more high frequency contents compare to the USNRC spectrum. It is between the Eurocode spectrum and USNRC spectrum and almost cover these two spectrum. The short period amplification is higher than the NEHRP spectrum.

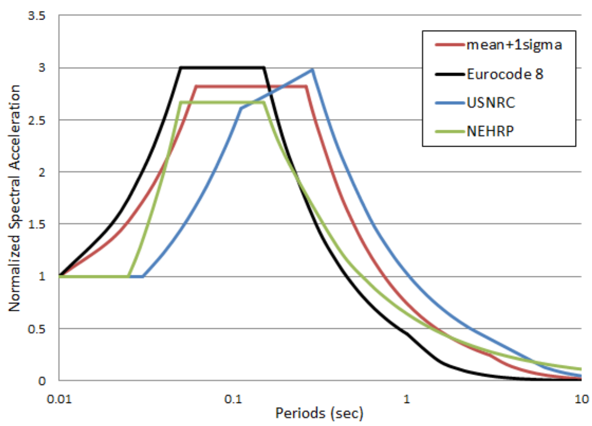

Fig. 3. Comparison of Developed Response Spectrum with Design Spectra in other Codes

Figure 4 shows the comparison with the spectrum shape of magnitude 5.8, Gyeongju Earthquake in 2016. The piecewise linear spectrum shape of Gyeongju Earthquake was also obtained as the same procedure for developed spectrum. The developed spectrum does not include Gyeongju Earthquake record because this study was performed before the earthquake occurred. However the spectrum shape is very similar to the Gyeongju Earthquake response spectrum. Therefore, it can be a verification example of developed spectrum.

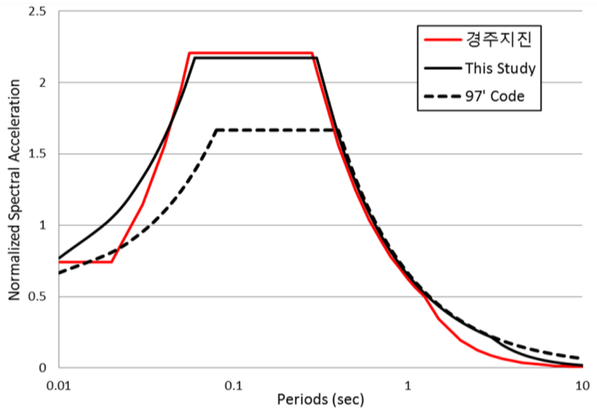

Fig. 4. Comparison of Developed Response Spectrum with the Response Spectrum Shape Recorded in 2016 Gyeongju Earthquake

4. Conclusions

This design response spectrum is the first one which is developed for Korean seismic design standard. Although the risk-targeted performance based response spectrum based on uniform hazard spectrum is recommended for nuclear facilities, this design response spectrum can be used for standard design when the construction site is not determined or the minimum spectrum of a site specific response spectrum.

ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIP) (No. 2017M2A8A4014828)

REFERENCES

[1] KMA. Domestic Earthquake List. Available from: http://www.kma.go.kr/weather/earthquake_volcano/domesticlist.jsp
[2] Boore, DM, J Watson-Lamprey, and NA Abrahamson. Orientation-independent measures of ground motion, Bull Seism Soc Am, 96(4a), 1502-1511. 2006.
[3] Kim, JK, Kim, JH, Lee, JH, and TM Heo. Development of Korean Standard Horizontal Design Spectrum Based on the Domestic and Overseas Intra-plate Earthquake Records, EESK Journal, 20(6), 369-378. 2016.