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# Example Performance-Based Site-Specific Design Earthquake for Nuclear Power Plant SSCs

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## 1. Introduction

In 1996, US NRC developed new criteria to determine a design ground motion including geologic, seismic and earthquake engineering considerations [1]. As a follow-up task to the revision, US NRC developed a performance based approach to define a site-specific earthquake ground motion [2]. The purpose of this approach is to provide guidance on the development of the site-specific ground motion response spectrum.

The newly proposed approach is introduced in this paper. And an example design ground motion was developed by the newly proposed approach using existing probabilistic seismic hazard analysis results.

## 2. ASCE/SEI 43-05 Method

*2.1 Seismic Hazard Evaluation*

According to the provision of the ASCE standard [3], the Design Basis Earthquake (DBE) for a nuclear power plant structure shall be based on a Probabilistic Seismic Hazard Assessment (PSHA). The seismic hazard curves and Uniform Hazard Response Spectrum (UHRS) can be obtained from the PSHA.

*2.2 Development of DBE Ground Motion*

To implement the graded approach for a seismic design, 20 Seismic Design Basis (SDBs) have been defined as specified in ANSI/ANS 2.26 [4]. Seismic Design Category (SDC) is defined by a quantitative probabilistic target performance. DBEs for SDC 1 and 2 are covered by the International Building Code. The ASCE/SEI 43-05 standard covers SDC 3, 4, and 5.

For SDC 3, 4 , and 5, the DBE ground motion shall be defined in terms of the Design Response Spectra (DRS), given by the following equations.

$$DRS = DF \times UHRS \quad (1)$$

*DF* is the design factor at each spectral frequency. For each spectral frequency at which the UHRS is defined, a slope factor, $A_R$, shall be determined from

$$A_R = SA_{0.1H_D} / SA_{H_D} \quad (2)$$

Then the design factor, *DF*, at this spectral frequency is given by

$$DF = Maximum(DF_1, DF_2) \quad (3)$$

$$DF_2 = 0.6(A_R)^{\alpha} \quad (4)$$

$DF_1$ and α are defined in the following table.

Table 1. Design Response Spectrum Parameters

| SDC | $H_D$ | $P_F$ | $R_P$ | $DF_1$ | α |
|---|---|---|---|---|---|
| 3 | $4x10^{-4}$ | $\sim 1x10^{-4}$ | 4 | 0.8 | 0.40 |
| 4 | $4x10^{-4}$ | $\sim 4x10^{-5}$ | 10 | 1.0 | 0.80 |
| 5 | $4x10^{-4}$ | $\sim 1x10^{-5}$ | 10 | 1.0 | 0.80 |

## 3. Regulatory Guide 1.208 Method

*3.1 Background of the New Approach*

Regulatory Guide 1.165 [1] provides general guidance to satisfy the requirement of 10 CFR 100.23. Regulatory Guide 1.208 [2] which provides an alternative guidance for defining a site-specific performance based ground motion response spectrum (GMRS) can be used as an alternative to Regulatory Guide 1.165 [1].

Figure 1 shows the procedures to define a site-specific performance based GMRS proposed in Regulatory Guide 1.208.

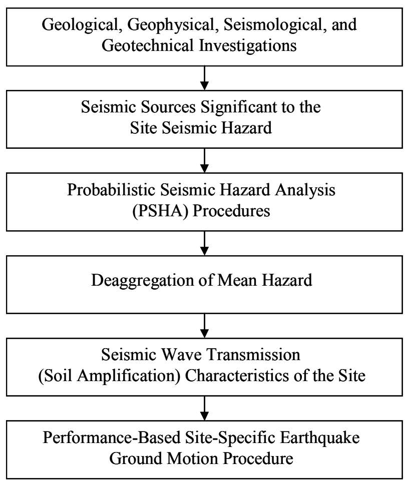

Fig. 1. Flow Diagram

*3.2 Horizontal Spectrum*

The performance-based, site-specific earthquake ground motion is developed by using similar methods to the development of the ASCE/SEI 43-05 standard [3] design response spectrum (DRS) that achieves the mean annual frequency of the onset of a mean significant inelastic deformation (FOSID) target performance goal ($P_F$) of 1E-05, and a horizontal exceedance probability ($H_D$) of 1E-04.

The horizontal performance-based, site-specific GMRS are obtained by scaling the site-specific mean UHRS by *DF* shown in equation (1).

### *3.3 Vertical Spectrum*

Vertical response spectra are developed by combining the appropriate horizontal response spectra and the most up-to-date V/H response spectral ratios appropriate for a site.

### *3.4 Location of the Site Ground Motion Response Spectrum*

The horizontal and vertical GMRS are determined in the free field on the ground surface. For sites with soil layers near the surface that will be completely excavated to expose a competent material, the GMRS are specified on the outcrop or hypothetical outcrop that will exist after excavation.

### *3.5 Determination of SSE*

The final safety Shutdown Earthquake (SSE) should be determined by the steps proposed in NUREG-0800 [5]. For some sites the GMRS may not contain adequate energy in the frequency range of engineering interest and, therefore, may not be appropriate as the site-specific plant SSE. For these situations the GMRS could either be broadened or enveloped by a smoothed spectrum.

## 4. Sample Calculation

The uniform hazard spectrum was derived from the probabilistic seismic hazard analysis results for a Korean NPP site [6]. Fig. 2 shows a comparison of the mean 1E-04 and 1E-05 UHRS. $A_R$ can be obtained from the two UHRSs by using equation (3).

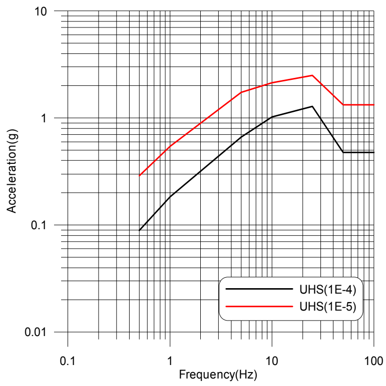


Fig. 2. Comparison of UHRS for 1E-04 and 1E-05 Annual Exceedance Probability

Fig. 3 shows a comparison of DRS according to the seismic design category proposed by ASCE/SEI 43-05 standard. The DRS for SDC 4 and 5 give the same GMRS of Regulatory Guide 1.208.

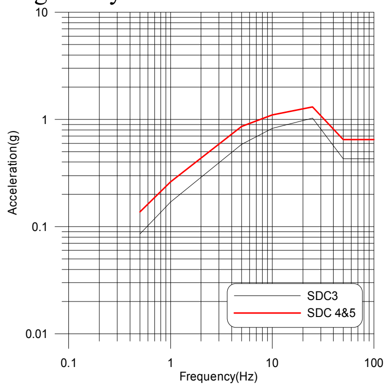


Fig. 3. Comparison of DRS According to the Seismic Design Category Proposed by ASCE Standard (without High Frequency Reduction)

## 5. Conclusion

In this paper, a newly proposed guideline for defining a performance-based, site-specific GMRS is introduced. As an example, a performance-based, site-specific GMRS for a Korean NPP site was developed by using existing PSHA results.

For developing the performance-based, site-specific GMRS, the hazard assessment should be provided for a minimum of 30 frequencies. This can give a smooth plot of spectral response across the frequency range of interest. So, it is necessary to develop appropriate PSHA input parameters, such as the seismic hazard map, attenuation equations, and to reduce the uncertainties in the PSHA results.

## ACKNOWLEDGEMENT

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