Development of a Uniform Hazard Spectrum for a Soil Site by Considering the Site Soil Condition

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1. Introduction

The standard response spectrum of the US NRC regulatory Guide 1.60 [1] has been used for the design of Korean nuclear power plants. The R. G. 1.60 spectral shape provides a generally conservative design basis due to its broad-band nature. Another issue associated with using this spectral shape as the design ground motion at the ground surface is that it leads to problems when applied at softer soil sites. In 1996, US NRC developed the new criteria to determine the design ground motion including geologic, seismic and earthquake engineering considerations [2]. As a follow-up task to the revision, US NRC developed the up-to-date seismic design spectra with empirical and analytical approaches [3,4]. The uniform reliability spectra can be obtained by using this proposed method. By using this design ground motion, the approximately consistent risk can be obtained at all sites.
The uniform reliability spectrum (URS) can be derived from the uniform hazard spectrum (UHS) by multiplying the scale factor determined from the seismic hazard curves and the required seismic margin. In this study, the conversion methods of the spectral shape for the soil site were estimated. And the uniform hazard spectrum for the example soil site was developed based on the uniform hazard spectrum at the hard rock site.

2. Uniform Hazard Spectra for Soil Site

2.1 Development of Uniform Hazard Spectra for Soil Site

For a soil site, modification of the rock site spectral shape is necessary to derive the soil spectrum for the design level. Several methods can be applied to obtain the uniform hazard spectrum for a soil site. In general, the following methods are used to derive the soil UHS for a site [3].

(1) Direct approach
(2) Simple scale factor approach
(3) More detailed scale factor approach

The direct approach models the soil response directly as a function of the earthquake magnitude and epicentral distance through a site specific attenuation relation. The soil hazard curves which will be used for the determination of the uniform hazard spectrum can be obtained from this approach. The advantage of this approach is the directness and consistency with the derivation of the rock hazard curves. However, this approach is unworkable for most sites due to the lack of soil specific information for the sites.

In the simple scale factor approach, the seismic hazard curve for the rock is represented as spectral acceleration and is simply scaled up (or down) at each frequency by the site soil condition. This approach is very simple, but the accuracy is low. To improve the accuracy, a more detailed scale factor approach can be used. This approach accounts for the additional features of ground shaking.
In this study, several kinds of simple scale factor approaches for the conversion of the rock spectrum to the soil spectrum were estimated.

2.2 Code Specified Methods

The code specified methods defines the amplification factor for the frequencies based on the specified rock design spectrum according to the local site condition. The local soil condition is classified as several groups with the N-value and shear wave velocity. In this study, the methods proposed by UBC (Uniform Building Code) and MOCT (Korean Ministry of Construction and Transportation) were used. The rock design spectra and amplification factors for the soil site proposed by these two are very similar.

2.3 Conversion Factor Methods

The conversion factor method proposed by Yoon et al. [5] and Masata et al. [6] were estimated. The conversion factor proposed by Yoon et al. is determined based on the site soil condition and soil characteristics in Korea.

Masata et al. developed a simple method for the conversion between a soil surface and rock surface earthquake motion including the nonlinear amplification/ deamplification effects of the soil layers overlying the bedrock. In this method, a simple conversion factor between the soil surface and rock surface motion is proposed for the peak acceleration, peak velocity and response spectra. The conversion factor can be derived from simple soil parameters, the N-value from the standard penetration test (SPT) and the soil depth. The soil UHS can be derived from the following equation.

$$S_S = \beta_S \cdot S_R(M, \Delta T, h) \qquad (1)$$

where, S_S and S_R are the spectral acceleration of the rock and soil site UHS, respectively. β_S is a conversion factor for the soil site.

3. Sample Calculation

The uniform hazard spectrum was derived from the probabilistic seismic hazard analysis for a Korean NPP site[7]. Fig. 1 shows the soil UHSs for various site soil conditions by the conversion factor method proposed by Masata et al.. The soil depth over the bed rock is 20m. It can be seen that the peak ground acceleration is reduced at the soft soil site (N=10), and increased at the medium and stiff soil site. The spectral acceleration in the low frequency region is increased at the soil site.

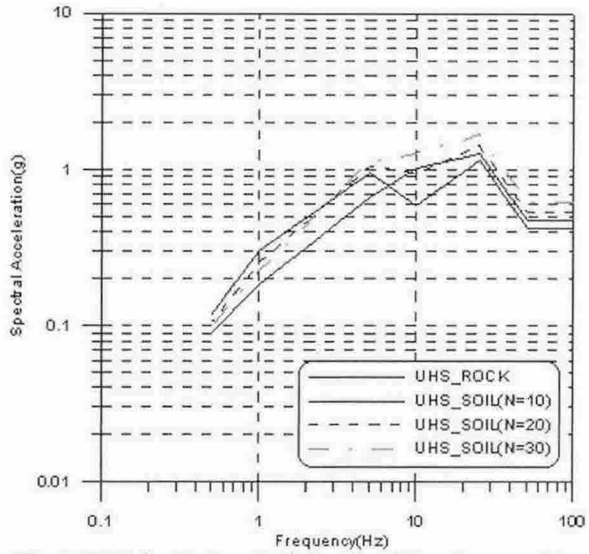

Fig. 1. UHS for Various Soil Site Condition Converted by Masata's Method

Fig. 2 shows the comparison of the soil UHSs converted by several scale factor approaches. It can be seen that the soil UHS converted by the conversion factor method is coincided with the soil UHSs converted by the code specified methods in the high frequency region, greater than 7Hz. The peak ground acceleration at the soil surface is very similar. The larger amplification of the code specified method in the low frequency region may be due to the coarse classification of the site soil condition. The conversion method proposed by Yoon et al [5] shows a larger amplification especially in the high frequency region.

4. Conclusion

In this study, several kinds of spectral shape conversion methods for a soil site were estimated. The conversion factor method proposed by Masata et al. is appropriate for the conversion of rock UHS to soil UHS. This method can be applied to various soil sites and layered soil conditions by using simple soil parameters. The code specified methods give a higher amplification in the low frequency region due to the simple classification of the site soil condition. The site soil condition is classified as four or five categories based on the soil characteristics. This simple classification is not enough to define the soil UHS for various site soil condition.

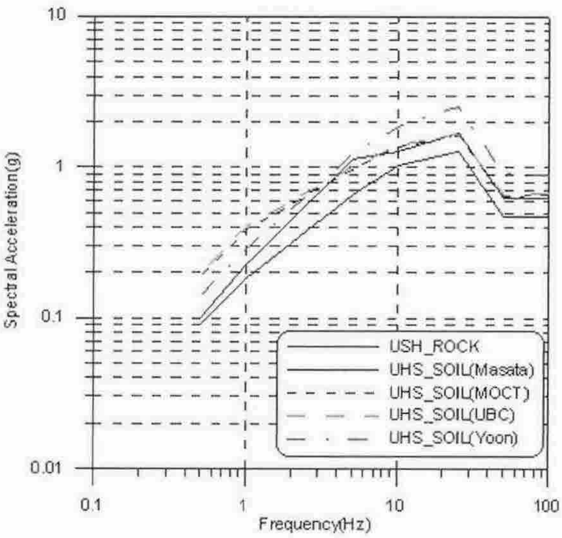

Fig. 2. Comparison of the Soil UHS by Various Methods

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