Development of Input Ground Motion for Seismic Analysis of Silo Structure in Low-and Intermediate-Level Radioactive Waste Disposal Facility

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1. Introduction

Silo is a large concrete structure to dispose of low- and intermediate-level radioactive waste (LILW) [1]. It is located in a stiff rock layer, but considering the long period of waste storage, it is necessary to understand the behavior of the silo for various earthquake disaster scenarios. Detailed seismic analysis can be used to assess the seismic behavior of the silo, and the determination of an appropriate input ground motion is important to improve the reliability of the analysis. However, for underground structures, unlike the nuclear power plant located on the ground surface [2], the determination procedure for input motion is not clearly established.

In this study, an input ground motion that can be used to evaluate the seismic behavior of silos in the LILW disposal facility was developed. A probabilistic seismic hazard assessment was performed for the site to derive the uniform hazard spectrum. In addition, the site response analysis was performed to derive the seismic motion of the control point in the analysis.

2. Probabilistic Seismic Hazard Analysis

2.1 Uniform Hazard Spectrum

Probabilistic seismic hazard analysis(PSHA) is a task that derives the annual exceedance probability (AEP) of earthquake intensities that can occur at the target site and requires various input parameters. In this study, the seismic source model was determined by expanding the existing seismic source model and used four area sources and two fault sources as the Eupcheon and the Z-fault. The seismic activity constant value was derived based on the earthquake list incorporating data from Japan and China near the Korean Peninsula. In the case of the attenuation equation that represents the propagation characteristics of earthquake waves according to the magnitude and distance, three attenuation equations developed based on domestic earthquake records were used.

A logical tree was constructed using the aforementioned source data and attenuation equation, and PSHA was performed for the disposal facility site. In order to consider the site-specific frequency characteristics of the input ground motion, a seismic hazard analysis was performed for a total of 10 frequencies in the range of 50 to 0.2 Hz as well as the peak ground acceleration(PGA). A uniform hazard spectrum was developed by collecting values for the same AEP from the finally derived hazard curves for all frequencies. The solid red line in Fig. 1 indicates the developed uniform hazard spectrum of 10-4 AEP. It shows considerable energy at high-frequency range of more than 10Hz. This spectral shape is similar to the recorded results of the Gyeongju and Pohang earthquakes.

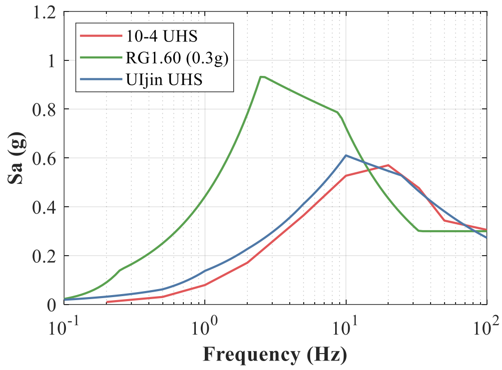

Fig. 1. Uniform Hazard Spectrum for LILW Disposal Facility Site

2.2 Response Spectrum Matching

To consider all the energy of each frequency presented in the target spectrum in the input motion of the seismic analysis, the recorded motion should not be simply amplified, but an artificial time history that is compatible with the spectrum should be created. The spectrum matching with seed motion is effective method to reflect the non-stationary characteristics of the real earthquake. In this study, spectral matching was performed with records at Myeonggye-ri during the Gyeongju earthquake as a seed earthquake. Figure 2 shows the acceleration time histories of the recorded and the matched motions.

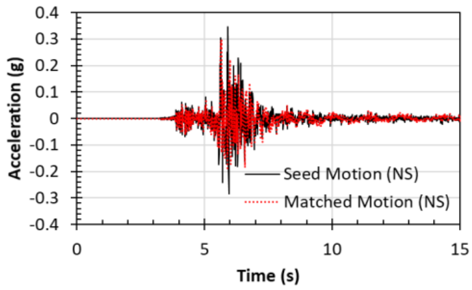

Fig. 2. Acceleration time histories for seed ground motion and spectral matched ground motion.

3. Site Response Analysis

3.1 Target Profile for Seismic Analysis

In LILW facility site, the six silo structures are located in the underground of about 80m to 130m below sea level. Therefore, in order to assess the seismic behavior precisely, it is important to reflect the interaction between the silo and the surrounding ground in the analysis model. The dynamic properties of the ground are not homogeneous, but in this study, a simplified ground column diagram as shown in Fig. 3 was determined for site response analysis based on the safety analysis report. It was largely composed of an upper soil layer and a lower rock layer, and the thickness of the lower rock layer of the silo was determined to be 40 m.

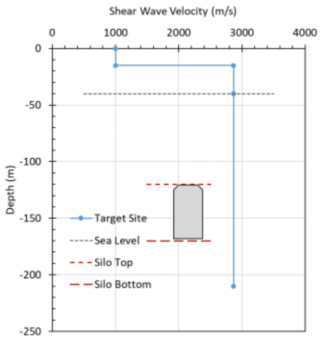

Fig. 3. Shear Wave Velocity Profile.

3.2 Site Response Analysis (Deconvolution Analysis)

The location of the input motion may vary depending on the method of analysis, but the lowest end of the model is generally utilized as a control point in consideration of the wave propagation. However, the location where the spectrum is defined is usually the outcrop surface of the stiff rock layer, so earthquake motions at the control points below the silo must be derived through site response analysis. This analysis is so-called as a deconvolution analysis. In this study, a one-dimensional site response analysis was performed for only the lower rock layer in the profile in Figure 3. Fig. 4 depicts the PGA profile by depth obtained through deconvolution analysis. Although the ground has a large shear wave velocity, both EW and NS direction results showed decreased PGA as it deepens from the surface. However, the decrease in PGA occurs intensively at about 60m in the upper part, and the width of change is not large near the silo and the lower rock ground.

Fig. 5 shows the time histories and the response spectrum of the developed input motion at the 40m below the silo. The vertical motion was not considered in this research.

4. Conclusions

The input ground motions for seismic analysis of silo structures were developed through PSHA and site response analysis for the LILW site. In order to improve the reliability of the input motion, it is necessary to further review the characteristics of the developed motion such as strong motion duration.

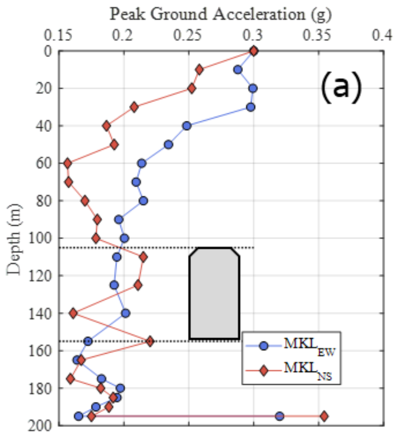

Fig. 4. Peak Ground Acceleration Profile from Site Response Analysis

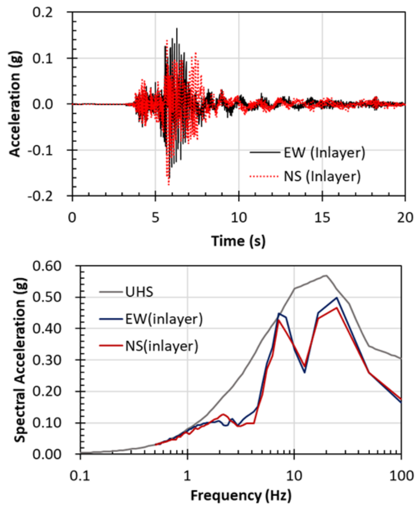

Fig. 5. Input Ground Motion for Seismic Analysis of Silo Structure

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