Evaluation of Seismic Hazard Curves at Soil Sites Considering Soil Amplification

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1. Introduction

The seismic design of the nuclear power plants (NPPs) has been based on a design earthquake which is consistent with the standard design response spectra [1]. After the concept of safe shutdown earthquake ground motion, which is based on the probabilistic seismic hazard analysis, was introduced, the existing deterministic method to evaluate design ground motions began to be changed into the probabilistic method [2]. With the introduction of performance based design, it is recommended that deign ground motions be consistent with uniform hazard response spectra (UHRS) with annual probability of exceedance of 10^{-5} [3]. Recently, it is proposed that design ground motions be consistent with uniform risk response spectra (URRS) rather than the UHRS. Thus, the conversion of UHRS to URRS has been studied [4-6].

Earthquake responses of nuclear power plants are greatly affected by soil-structure interaction. Therefore, it has been studied how to obtain UHRS/URRS at soil sites from those at the bedrock level considering soil-amplification effects. In this study, seismic hazard curves at soil sites will be computed from those at the bedrock level and the effects of soil amplification will be investigated.

2. Methodology and Application

Seismic hazard curves at soil sites are computed from those at the bedrock level considering the effects of soil amplification. The soil amplification is described by a amplification function, AF(*f*), where *f* is a generic oscillator frequency. AF(*f*) is defined as the ratio of the spectral acceleration at soil sites, $S_a^s(f)$, to that at the bedrock level, $S_a^r(f)$. The spectral acceleration $S_a^s(f)$ is calculated using the iterative equivalent-linear site analysis code, ProSHAKE 2.0. From the calculations for various ground motions, the statics of the amplification function are estimated. The seismic hazard at soil sites is computed by convolving the site-specific hazard curve at the bedrock level with the probability distribution of the amplification function AF(*f*).

The above methodology is applied in order to calculate seismic hazard curves at the generic soil sites in Table I. The hazard curves at the bedrock level is given by the typical normalized spectral acceleration hazard curves for eastern U.S. [4]. In this application, a total of 59 strong ground motions are considered. Their spectral accelerations at the bedrock level are shown in Fig. 1. The spectral accelerations at the soil surfaces are calculated. The amplification functions for the considered 59 motions are shown in Fig. 2. The amplification functions at 1 and 10 Hz are regressed in terms of the spectral accelerations at the bedrock level and their statics are determined assuming log-normal probability distributions (Fig. 3). Then, the seismic hazard curves at soil sites at 1 and 10 Hz are obtained as shown in Fig. 4.

Table I: Generic Soil Sites

(a) Profile

Depth (ft)	Generic soil								
	1	2	3	4	5	6	7	8	9
0 ~ 55	P1	P1	P2	P1	P3	P2	P2	P4	P4
55 ~ 100	P1	P1	P2	P2	P3	P3	P3	P4	P4
100 ~ 200	P1	P2	P2	P3	P4	P3	P4	P4	P5
200 ~ 500	P2	P3	P3	P4	P4	P5	P5	P5	P5
500 ~ 1000	P3	P4	P5	P5	P5	P5	P5	P5	P5
1000 ~	P5	P5	P5	P5	P5	P5	P5	P5	P5

(b) Properties

Generic soil	S-wave velocity (ft/sec)	Specific weight (lb/ft^3)
P1	1200	125
P2	2000	130
P3	4000	135
P4	6000	145
P5	9200	155

It can be observed that the soil amplifications at 1 Hz are not large for the generic soils 5 to 9 in Fig. 3(a). Thus, the hazard curves at the soil surface are very close to that at the bedrock level as shown in Fig. 4(a). The regressed amplification functions at 10 Hz for the generic soils 1 to 8 are observed to decrease as the spectral acceleration at the bedrock level in Fig. 3(b). The decreases result in the abrupt changes of slopes in the log-log plot of the hazard curves on the soil surfaces in Fig. 4(b) although the slope in the hazard curve at the bedrock level is almost constant. The seismic risk is estimated assuming the slope in a hazard curve is constant [4, 5]. Thus, the changes of slope observed in Fig. 4(b) can affect the seismic risk. For soil sites, the effects must be considered when the seismic risk is examined.

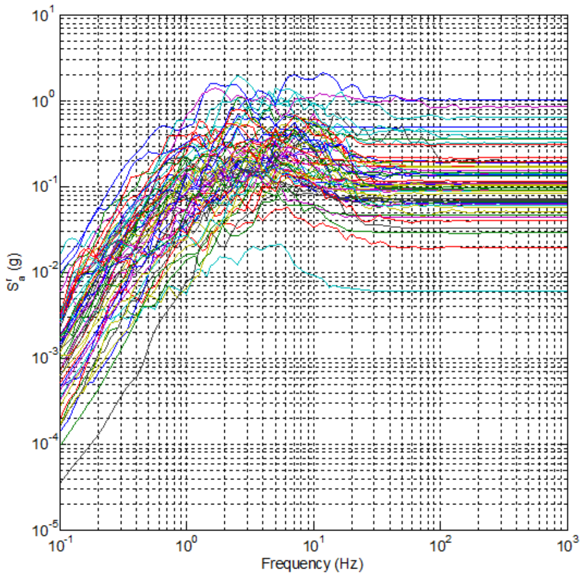


Fig. 1. Spectral accelerations at the bedrock level

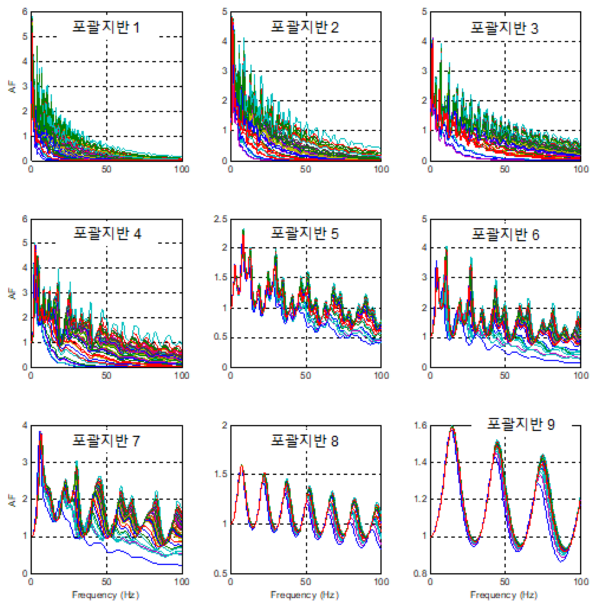
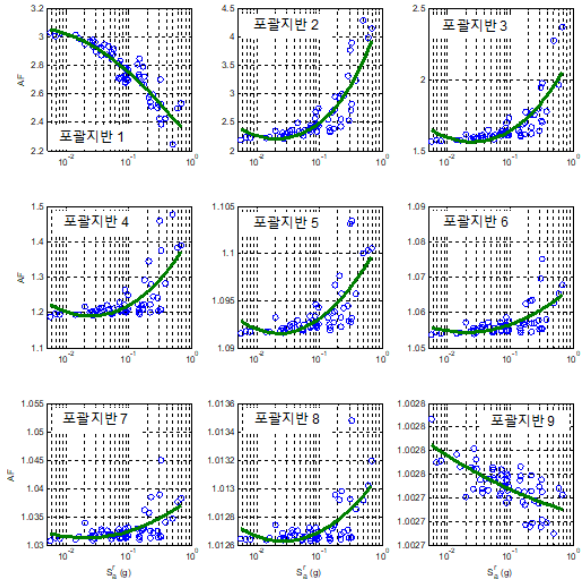


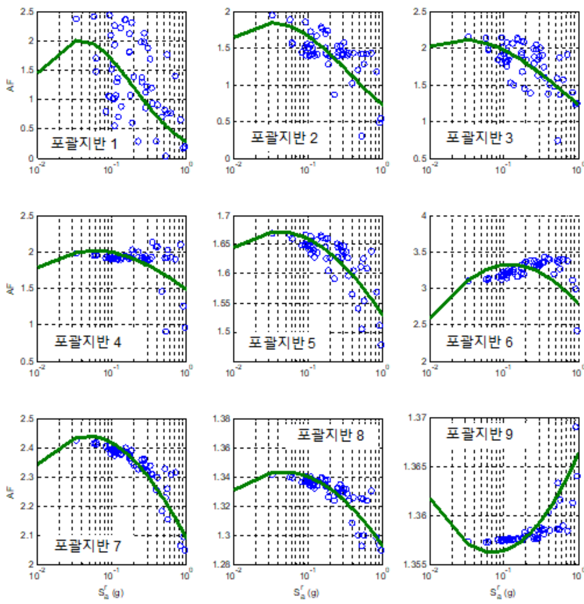
Fig. 2. Amplification functions

3. Conclusion

In this study, seismic hazard curves at soil sites were computed from those at the bedrock level. It was observed that the slopes in the log-log plot of the curves can be varying. Since the changes can affect the seismic risk, it must be considered in the risk analysis for soil sites.

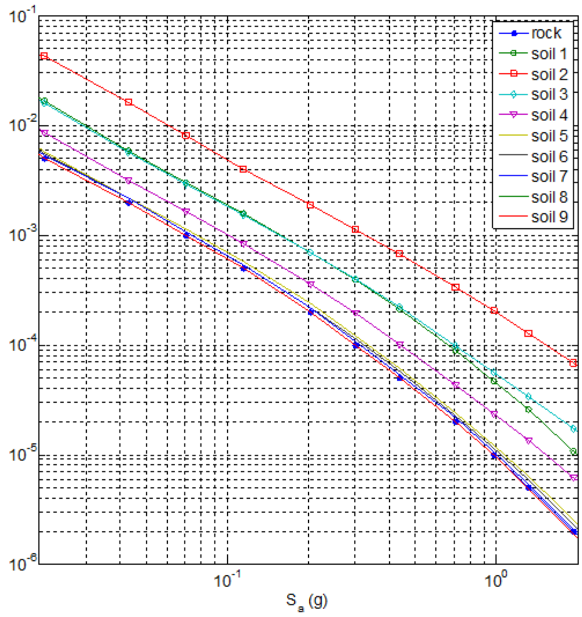


(a) $f = 1$ Hz

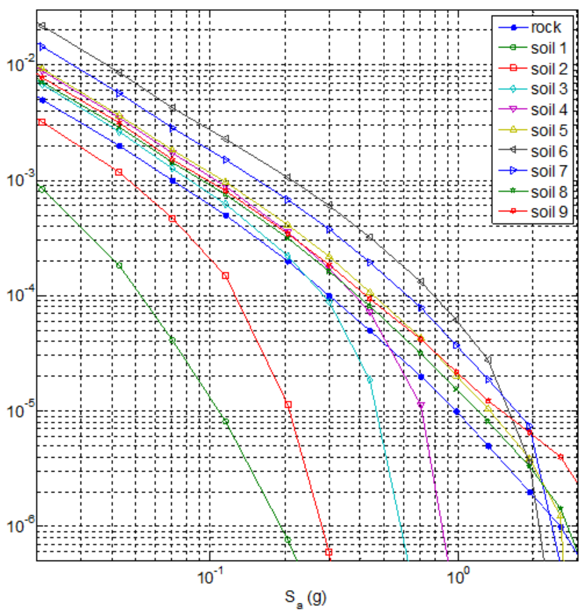


(b) $f = 10$ Hz

Fig. 3. Regressions of the amplification functions



(a) *f* = 1 Hz



(b) *f* = 10 Hz

Fig. 4. Seismic hazard curves at the soil surfaces

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