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Effects of the Spatial Variability of Soil Properties on the Liquefaction Vulnerability Indicators

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Extended Abstract

Liquefaction is a phenomenon by which saturated loose cohesionless soils subjected to dynamic loading lose their strength during earthquakes, which often causes significant damage to infrastructure. Several methods have been developed to evaluate the possibility of liquefaction, and usually quantified in terms of the factor of safety (FS) against liquefaction, which is defined as the ratio of the cyclic resistance ratio (CRR) and cyclic stress ratio (CSR). However, FS does not show the degree of liquefaction severity at a liquefaction-prone site because it represents the liquefaction potential of soil only at a particular depth. In addition, not all liquefaction triggering results in land damages. To overcome these limitations of FS, Iwasaki et al. [1] proposed the liquefaction potential index (LPI) which is a single-valued parameter that provides integration of liquefaction potential over the depth of a soil profile. Although LPI is the most widely used vulnerability index to quantify the severity of liquefaction, some disadvantages have been pointed out as liquefaction severity is assessed only by safety factor. Alternatively, one-dimensional volumetric reconsolidation settlement (S_{V1D}) [2] and liquefaction severity number (LSN) [3] have been proposed to overcome LPI drawbacks considering the volumetric strain. The soil properties for liquefaction assessment are generally identified through field tests such as the cone penetration test (CPT) and the standard penetration test (SPT). However, nearly all natural soils are highly variable in their properties and are rarely homogeneous. Theses uncertainty is unavoidable and may lead to an unexpected system response. In particular, the soil properties are not random, but show a spatial correlation. Therefore, the spatial variability of the soil properties should be considered to obtain more accurate and reasonable results in the probabilistic analysis, and it can be characterized using random field theory.

In this study, the effects of the spatial variability of soil properties on liquefaction vulnerability indicators were investigated. A CPT-based liquefaction triggering procedure proposed by [4] was used to obtain FS because CPT can yield a continuous soil properties with depth, and it can be effectively used to identify the spatial variability of soil properties. CPT data for liquefaction vulnerability assessment were obtained from three different sites, and the spatial variability of cone penetration resistance was evaluated by the autocorrelation model fitting method. The random fields were generated based on Karhunen-Loeve expansion considering the evaluated spatial statistical properties. The FS against liquefaction was calculated by a CPT-based simplified procedure, and post-shaking settlements were computed by the procedure reported by [5]. Then three liquefaction vulnerability indicators (LPI, S_{V1D}, and LSN) were calculated from the results of liquefaction analysis. A series of Monte Carlo simulations was conducted to identify the statistical properties of liquefaction vulnerability indicators. In conclusion, the statistical characteristics of the liquefaction vulnerability indicators were compared, and the effects of the spatial variability of soil properties on the liquefaction vulnerability indicators were identified.

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