EVALUATION OF LIQUEFACTION TRIGGERING UTILIZING PERTINENT UNCERTAINTIES

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The requirements to design structures subjected to strong ground shaking have attracted the attention of many researchers. A designer should consider pertinent problems of liquefaction to make sure the safety and reliability of the structures. The soil liquefaction phenomenon is an important issue of concern to earthquake geotechnical engineers in recent years. Liquefaction happens when saturated granular media loses its shear strength due to the increase in pore water pressure under seismic loading. With the occurrence of this phenomenon, saturated sandy soils will lose their strength and soil particles will flow. This phenomenon has been observed in many earthquakes such as Alaska (1964), Niigata (1964), Loma Prieta (1989), Kobe (1995), Chi Chi (1999) and recently in Bushehr, Iran (2013). Soil improvement techniques are usually expensive, hence accurate evaluation of soil liquefaction potential can reduce the overall cost of projects in addition to provide the safety of structures.

Selection of geotechnical parameters is always one of the challenging issues for geotechnical engineers due to intrinsic uncertainties in soil and rock structures. Engineers usually apply safety factors to cover the uncertainties. This approach will lead to increase the project cost. It also could not be reliable enough since there is no explicit relation between factor of safety and probability of failure and it makes the engineering judgment to be complicated (Duncan, 2000). In recent years, probabilistic methods have been developed to overcome this deficiency.

In general, it is possible to categorize geotechnical uncertainties into two main groups: inherent uncertainties and epistemic uncertainties (Griffiths and Fenton, 2007). Soil inherent uncertainties are due to the nature of variability of soil parameters in different locations and time. Consequently, their effects should not be disregarded. The second category of uncertainties is because of the lack of information and knowledge in geotechnical engineering. Epistemic uncertainties include measurement errors, statistical uncertainties, and model uncertainties. Considering the uncertainties in geotechnical engineering, it is not recommended to take soil parameters with deterministic values. Therefore, the appropriate method is application of the probabilistic approach to determine soil parameters for design purposes. Reliability methods which are based on probabilistic approach provide the opportunity to quantify uncertainties and can be used as a supplementary tool for deterministic methods. Reliability methods are able to capture uncertainties considering variability of soil parameters and also to determine factor of safety proportional to the acceptable risk.

Liquefaction is a probabilistic phenomenon due to uncertain nature of earthquake and variability in soil deposits. Regarding to the pertinent uncertainties, it seems that deterministic method is not suitable for liquefaction evaluation. It is possible to categorize the uncertainties of liquefaction into two groups: parameter uncertainties and model uncertainties. The present research tries to capture parameter uncertainties in the evaluation of liquefaction process.

Reliability analysis methods are usually divided into three categories: analytical, approximated, and simulation methods.

Simulation methods are among accurate reliability analysis methods. These methods predict the probability of events by simulating stochastic input parameters and implementing in repetitive calculations. In mathematics, these methods have been used for complex problems which their close-form solution is not possible (i.e. large degree of integration). Nowadays, regarding to rapid development in computer technology, utilization of these methods has been increased in engineering problems. Monte Carlo simulation method is one of the most applicable methods of this category.

In the present research reliability analysis of liquefaction triggering has been done using Monte Carlo simulation. For this purpose, the factor of safety function is selected as performance function and the parameters of earthquake magnitude (M_w), maximum horizontal acceleration (a_{max}/g), total stress (σ_v), effective stress (σ'_v), fine content percent (FC), and SPT blow count (N_{SPT}) are chosen as stochastic variables. The statistical definition of the stochastic parameters includes probability density function (PDF), coefficient of variation (COV) and correlation coefficient. Then, evaluation of liquefaction has been done using Idriss and Boulanger (2010) method.

To verify the application of the proposed method to analyze liquefaction potential, the Loma Prieta earthquake (October 1989), has been studied. Comparison between the results of deterministic approach and actual occurrence of liquefaction in this case study indicates that deterministic approach is not reliable enough to predict the event. For example, in some cases despite the fact that the factor of safety is more than one, liquefaction had occurred but in some cases which the factor of safety is less than one, there was no evidence of liquefaction occurrence. On the other hand, the results of Monte Carlo simulation have a good accuracy to predict liquefaction and therfore this method is recommended for any other sites.

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