A CPT-based Evaluation of Liquefaction Probability via Genetic Algorithms
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ABSTRACT
Based on the reliability theory, liquefaction probability calculation involving inequality and/or equality constraints becomes a constrained optimization problem. The genetic algorithms (GAs) are popular approaches to solve constrained optimization because of their simplicity and ease of implementation. This paper aims to develop an evaluation method of liquefaction probability via GAs. The total 226 CPT-based case histories of liquefaction and non-liquefaction are collected from Juang et al. (2003) to calculate the PL. The analysis results show the GAs model is suitable for liquefaction probability problem. The relation between factor of safety (FS) and PL based on the cases studied is obtained: PL = 1/(1 + FS9.117).

KEY WORDS: Liquefaction probability; reliability index, CPT-based data; genetic algorithms.

INTRODUCTION
Earthquake-induced soil liquefaction in loose sand layers often causes settlement and tilting of buildings. Structural failure caused by liquefaction has been observed in many earthquakes (e.g., the 1964 Niigata, Japan earthquake, the 1995 Hyogoken-Nambu, Japan earthquake, the 1999 Kocaeli, Turkey earthquake, and the 1999 Chi-Chi, Taiwan earthquake) (Ishihara, 1993; Earthquake Engineering Research Institute, 2000; Ku et al., 2004). Many empirical methods for assessing liquefaction hazard have been developed based on analysis of case histories of liquefaction and non-liquefaction around the world. The probabilistic evaluation of liquefaction is desirable because many key influence factors and environmental statues, such as earthquake force, soil properties and groundwater for earthquake-induced soil liquefaction are variability. Several approaches based on Hasofer-Lind reliability method are available for evaluating liquefaction probability (e.g., Haldar and Tang, 1997; Juang et al., 2000; Lee et al., 2007). In the Hasofer - Lind method, generally known as the advanced first order second moment (AFOSM) method, the reliability index RI is defined as the minimum distance from mean values of variables to the boundary of the failure region, in the vector direction of directional standard deviations (σ) (Low, 1997). The AFOSM relies on a constrained optimization scheme to determine the reliability index involving inequality and/or equality constraints. In solving constrained optimization problems, genetic algorithms (GAs) or classical optimization methods have been the most popular approach, because of their simplicity and ease of implementation.

The genetic algorithms methods (GAs), which are the best known optimization techniques, are generic search methods based on the mechanics of natural genetics and natural selection. GAs are computationally easy and provide robust optimization search in complex space. Most applications of GAs work well to solve the constraint handing optimization problems (i.g. Kalyannoy, 2000; Sun et al., 2008; Nedim, 2009; Subbaraj and Rajnarayanay, 2009). This paper aims to develop an evaluation method of liquefaction probability via GAs proposed by Kalyannoy(2000). The 226 case histories of liquefaction and non-liquefaction are collected from the document of Juang et al. (2003) to calculate the liquefaction probability. For checking the implementation of GAs in liquefaction probability evaluation, the analysis results of GAs are also compared with the knowledge-based clustered partitioning method (KCPM) reported by Lee et al.(2007).

AN OVERVIEW OF ELEMENTS RELATED TO PROPOSED MODELS
Hasofer–Lind reliability index
Low (1997) interpreted the Hasofer – Lind reliability index, RI, as the ratio of the size of the dispersion ellipsoid that touches the failure surface to the size of 1-σ dispersion ellipsoid. The solution of RI, the minimum distance search, is obviously an optimization problem. Low (1997) and Low and Tang (1997) demonstrated this solution approach using the Excel Solver. As noted previously, several other algorithms such as Lagrange's multiplier (Shinozuka, 1983), polynomial technique (Chowdhury and Xu, 1995) and KCPM (Lee et al., 2007) are also available. The Hasofer – Lind second moment reliability index RI is defined as (Hasofer and Lind, 1974; Ditlevsen, 1981):

\[ RI = \min_{x \in \mathcal{X}} \sqrt{(X - m)^T H^{-1}(X - m)}. \]  

where \( X \) = the vector representing a set of random variables \( X_i \); \( m \) = the