Investigation of parameter uncertainty in liquefaction probability based on meta-heuristic algorithms and Bayesian mapping function

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Abstract

Liquefaction evaluation methods in sandy soils is generally based on the deterministic analysis. In the deterministic approach, certain and non-dispersion parameters are considered. Furthermore, in these methods, establishment of exact correlation between the probability of liquefaction (P_L) and the factor of safety (F_s) is not possible. This problem is solved using the reliability analysis. In this paper, effect of the parameter uncertainty in liquefaction probability, based on the Gene Expression Programming (GEP) model for liquefaction resistance and potential evaluation based on Standard Penetration Test (SPT) is investigated. In order to verify the model, GEP results are compared with the results based on Idriss and Boulanger approach (۲۰۱۰). Then, First-Order Reliability Method (FORM) by using a hybrid of Particle Swarm Optimization and Genetic Algorithm (PSO-GA) in MATLAB۲۰۱۳a, as a robust optimization method is used to determine the reliability index (β). Bayesian mapping function is utilized to infer the relationship between probability of liquefaction and reliability index. Finally, effect of the level of parameter uncertainty on the liquefaction probability by development the Bayesian mapping functions, are investigated by using the β-P_L curves.

Keywords: Liquefaction, Gene Expression Programming, First Order Reliability Method, Hybrid algorithm (PSO-GA), Bayesian mapping function.

۱. INTRODUCTION

Liquefaction occurrence is one of the most common causes of structural failures during earthquakes in saturated loose granular alluvium areas. Usually due to earthquake tensions in these regions, increasing pore-water pressure and therefore, reduction and loss of soil strength will happen and finally, soil reaches liquid consistency state. This phenomenon accompanied by remarkable settlements and cracks, eruption of mud and water, sand boiling and ground water seepage through the pore spaces between particles of un-consolidated earth materials. Due to difficulties and high costs of intact and high quality sample preparation and also existence of simple methods based on on-site tests such as Standard Penetration Test (SPT), Cone Penetration Test (CPT), Becker Penetration Test (BPT) and Shear wave velocity tests, geotechnical engineers prefer these procedures to use for evaluating soil liquefaction potential.

A new comprehensive approach for soil liquefaction assessment which considers uncertainty, is statistical analysis and specially reliability analysis. Many researches in this field has been done. Juang et al. (۲۰۰٤) analysis soil liquefaction based on CPT databases. They investigated the uncertainties in the Robertson and Wride model by using First-Order Reliability method (FORM) [۱]. They considered parameter and model uncertainties in their probabilistic model. Hwang et al. (۲۰۰٤) based on statistical analysis and Chi Chi (۱۹۹۹) earthquake data, estimated the probability density function of cyclic shear induced-earthquake. They used First-Order Second Moment (FOSM) to obtain a correlation between probability of liquefaction (P_L) and cyclic stress ratio (CSR) [۲]. Juang et al. (۲۰۰٦) by using the artificial neural network, presented a new relationship for soil liquefaction assessment based on ۲۰۰ CPT databases [۳]. Lee at el. (۲۰۱۰) investigated liquefaction data from one of the cities which was seen much damage in Chi Chi (۱۹۹۹) earthquake, Yuanlin. They considered uncertainties in dynamic soil resistance parameters in their liquefaction evaluation model. To determine the cyclic soil shear strength, they used SPT and CPT methods and illustrated a good agreement between the results of both models based on two methods [٤].