Finite Difference Numerical Evaluation of Liquefaction with Effective Stress Method and Numerical Estimation of Liquefaction in Bandar Abbas's Mosque Project (Case Study)

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Extended Abstract

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Introduction

Estimation of Liquefaction is one of the main objectives in geotechnical engineering. For this purpose, several numerical and experimental methods have been proposed. An important stage to predict the liquefaction is the prediction of excess pore water pressure at a given point. In general, there are two important methods for soil dynamics analyses, fully coupled effective stress and uncoupled total stress analysis. The main purpose of this study is to evaluate the model capacity of the finite difference software, FLAC, based on effective stress analysis methods to predict the excess pore water pressure during seismic loading. A level ground centrifuge test conducted during the VELACS project on the Nevada sand with a density of 40%, was utilized to calibrate the numerical model. After the validation of the numerical model, a model was conducted to predict excess pore pressure and consequently the liquefaction for the site of Bandar Abbas Mosque.

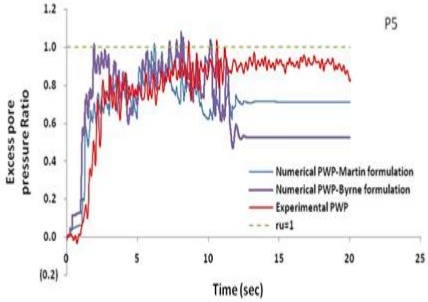
Theoretical bases

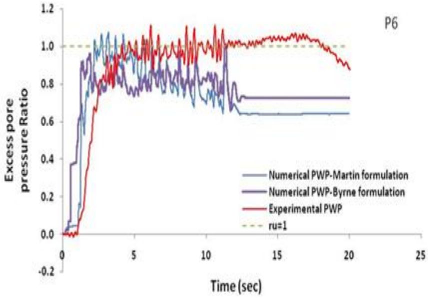
A fully coupled u–P formulation, where pore pressures and displacements are computed simultaneously and interactively at each time step, is used in FLAC software. This feature is used to simulate the excess pore water pressure time histories during cyclic loading.

The finite difference based software, FLAC, used the Finn model that incorporates two equations correlating the volumetric strain induced by the cyclic shear strain and excess pore water pressure produced during cyclic loading. As mentioned above, the pore water pressure generation can be computed from two sets of equations: Martin et al. (1975) and the Byrne (1991) formulations in which the volumetric strain that was produced in any cycle of loading is depended on the shear strain that was formed during that cycle as well as the previously accumulated volumetric strain.

Modeling and Results

The VELACS model # 1 centrifuge test representing a level ground site constituted of the Nevada sand at 40% relative density has been numerically simulated in the current study to validate the numerical model. The centrifuge model contains a laminar box with slipping “rings” that allows differential horizontal displacements. This was simulated in the FLAC model by free-field boundary conditions which prevent reflection of the waves in the side walls. Figure 1 shows comparison of EPWP time histories ratio of numerical modeling and centrifuge test. Static analysis was carried out before dynamic analysis in order to find initial stress and strain state. At the next stage, the dynamic loads were applied at the base of the model and dynamic analysis was performed.





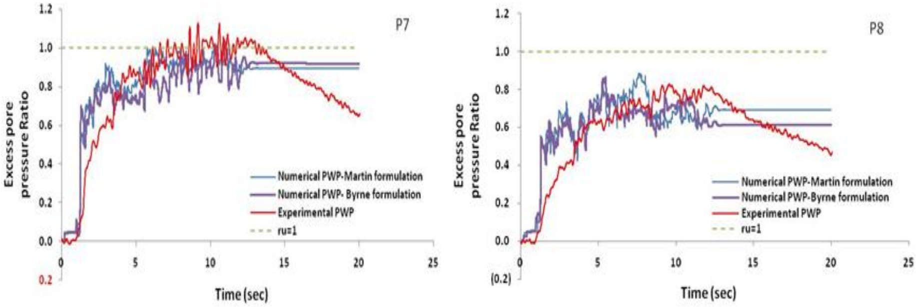


Figure1.Comparison of EPWP time histories ratio of numerical modeling and centrifuge test

The Bandar Abbas mosque project is located approximately 500 meters from the coast. In the project, due to the groundwater level and the existence of loose layers of silt, investigating the potential of liquefaction is necessary.

For numerical modeling the results of the general soil mechanics test on soil samples and standard penetration test performed on the site were used to calibrate the parameters and select the model constants.

Conclusion

The results of numerical modeling have been matched to experimental results of the centrifuge test using both Martin and Byrne formulations, except for the case of 5 m the numerical model has predicted lower excess pore water pressure values than the experimental values. This may be originated from the fundamental assumption of the Martin et al. (1975) EPWP theory, in which excess pore water pressure is directly related to the relevant volume changes. On the other hand, the Martin et al. (1975) model was adopted for one-dimensional measures of shear strain, while, in a 2D analysis under both horizontal and vertical shakings, there are three strain rate measures. FLAC uses some assumptions to solve this problem and it can affect the results.

The results of the numerical model showed liquefaction to a depth of about 5 meters that is almost compatible with the results from the lab, which has declared that the depth 2 to 5 m is liquefiable.

With careful selection of numerical model parameters one can generally use the simulation results to have a general sense on the pore water pressure generation and liquefaction prediction.

Keywords: Soil liquefaction, excess pore water pressure, centrifuge test, numerical approach, constitutive model.

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