NUMERICAL SIMULATION AND CENTRIFUGE MODELING OF A LAYER OF LIQUEFIABLE SOIL SUBJECT TO CYCLIC LOADING

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Liquefaction is a phenomenon in which the strength and stiffness of a soil is reduced by strong ground motion or earthquake shaking or other rapid cyclic loading. Liquefaction has historically been responsible for extensive damage including landslides, differential settlements, lateral spreading, structural and earth system failures throughout the world. Liquefaction problems have received a great deal of attention, and great efforts have been made to understand the basic mechanism and phenomenon [1]. However, due to the complexity of liquefaction problems, such as nonlinearity of responses, sudden phase transition from solid to liquid behavior, material instability, interaction and relative movement between the porous soil skeleton and interstitial water, limitations on experimental and numerical techniques, material model formulation and so on, reliable and accurate predictive methods have yet to be developed.

A saturated soil behaves as a two-phase system and any comprehensive analysis should take into consideration the interaction between the soil skeleton and the interstitial fluid. In this paper, the governing equations of motion of the soil mixture are coupled with the global mass balance equations, and necessary assumptions are made to obtain the equivalent Biot's equations from the general balance equations. The finite element method (FEM) is considered as a powerful numerical technique in solving geotechnical engineering problems. However, every finite element model has to be terminated at some finite boundary. For wave propagation problems, the usual finite boundary of the finite element model will cause the seismic waves to be reflected and superimposed on the progressing waves. In this paper, we present a coupled finite element-infinite element numerical model for simulating semi-infinite soil media subjected to cyclic loading. An enhanced cyclic fuzzy-set plasticity constitutive model is implemented in the fully coupled finite element formulation [2].

The accuracy of numerical analysis needs to be validated. However, due to the general random nature of earthquakes, most field liquefaction failures have occurred at sites without instrumentation. The advent of centrifuge modeling that incorporates scaled dynamic events brought light on the development of proper numerical techniques to simulate the consequences of soil liquefaction. Centrifuge testing creates stress conditions in the model that closely simulate those in the full-scale prototype, so that the behavior of the model can approximate that of the prototype. Since 1988, the University of Colorado – Boulder (CU) has operated a 400 g-ton centrifuge which is furnished with servo-controlled electro-hydraulic shake table that is mounted on the swing platform of the centrifuge, which can be operated inflight to produce earthquake-like motions. Comparison of numerical predictions and centrifuge experiment on a layer of liquefiable soil is presented in this paper.

References

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