MICRO-MECHANICAL MODELING OF WATER-INTERLAYER FORMATION IN LIQUEFIABLE LAYERED SAND DEPOSITS

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Lateral spreading and ground flow failure are pervasive problems associated with earthquake induced site liquefaction. These site problems often occur in mildly-sloping granular deposits and are linked with very costly structural damage to bridges, dams, buried pipes, and buildings of all types. Case histories show that lateral spreading of layered deposits occurs during ground shaking as well as after seismic excitations have ended. For such deposits, field and centrifuge test evidence reveals that water interlayers often form when a liquefied layer is overlaid by a less pervious stratum. Such interlayers serve as a sliding surface for the sloping top stratum and lead to a flow failure that may occur even after the end of shaking. The associated lateral displacements may reach several meters.

A continuum-discrete hydromechanical model was utilized in this study to analyze the coupled meso-scale pore fluid flow and micro-scale solid phase deformation of saturated granular deposits when subjected to dynamic base excitations. The fluid motion was idealized using averaged Navier-Stokes equations, and the discrete element method was employed to model the solid particles. The fluid-particle interactions were provided by established semi-empirical relationships. Numerical simulations were conducted to assess the liquefaction, formation of water interlayer and lateral spreading of a mildly-sloping layered site. The analyzed site consisted of a two-layer sandy soil deposit. More specifically, a relatively loose granular layer of somewhat high permeability was overlain by a top stratum with a lower permeability. Periodic boundaries and a high gravitational field were used in order to reduce the number of particles, required to achieve a realistic simulation, to a computationally manageable value. The performed simulations showed that the permeable loose granular layer exhibits a contractive response when subjected to a cyclic loading. The resultant volumetric deformations are associated with an increase in pore fluid pressure and an upward pore fluid movement. This upward movement is hindered by the low permeability of the top stratum. Thus, a portion of the ascending pore fluid gets trapped beneath this top stratum and forms a water interlayer. This interlayer persists after the end of shaking (for a time window that depends mostly on the top layer permeability). The formation of this interlayer results in a significant lateral displacement of the top stratum. The outcome of the conducted simulations was consistent with experimental observations from physical centrifuge models and recorded case histories, and revealed subtle valuable information on the mechanism of water interlayer generation and associated lateral spreading.

Keywords: DEM, liquefaction.