Centrifuge Modeling of Pile Foundation Response to Liquefaction and Lateral Spreading: Study of Sand Permeability and Compressibility Effects Using Scaled Sand Technique

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ABSTRACT

Great effort has been made by several researchers to understand the failure mechanism of pile foundations subjected to liquefaction induced lateral spreading. With the aim of formulating better design methods, a number of centrifuge model tests on piles in liquefied sand have been made since 1964, especially since the pile damage at Kobe became apparent. Centrifuge tests have clearly shown that the permeability of the liquefiable soil is a key factor. In principle there are two ways to model the prototype soil's permeability in the centrifuge. One of them is to increase the viscosity of the pore fluid used in the model while using the same soil in model and prototype. The second way is to use a soil in the centrifuge model which has a finer grain size but is otherwise similar to the prototype sand, and use water as the pore fluid in the centrifuge. As demonstrated in this research, the second method, to be referred to as the Scaled Sand Technique, is able to simulate similar pile behavior to centrifuge tests conducted by increasing the viscosity of the pore fluid, only when the permeability and compressibility of the soils are matched. The previous observation includes a second key factor in the simulation of lateral spreading and the effect on pile foundations: the soil compressibility. This research has shown that the maximum bending moment in a single pile subjected to lateral spreading will tend to decrease when the permeability or compressibility of the liquefied soil increases. The effect of increased soil permeability and compressibility in reducing the bending moment seem to have the same common origin. That is, a liquefied soil of higher permeability and compressibility will induce less pore pressure reductions around the pile and will dissipate these pore pressure reductions more rapidly. Analytical and design procedures need to be developed that account for the influence of these and other factors on those pore pressure reductions near the pile. Current analytical and design methods based partially on centrifuge modeling, but which ignore the influence of the excess pore pressure reduction on pile foundation response, and especially those which do not take into account the wide range of bending moments that may occur due to the influence of the permeability and compressibility of the sand, are bound to have limited predictive power.