Performance-based Assessment of Liquefaction-induced Downdrag on Piles

Deep foundations constructed in liquefiable soils are vulnerable to significant settlement and downdrag during earthquakes, posing a persistent challenge for safe and economical pile design. This presentation synthesizes findings from an integrated experimental and numerical research program aimed at advancing the mechanistic understanding of pile response under liquefaction-induced downdrag. Large-scale centrifuge model tests were conducted at the UC Davis Center for Geotechnical Modeling to simulate soil-pile systems subjected to sequences of earthquake motions. The experiments captured the coupled evolution of excess pore pressures, axial load transfer, and settlement using high-resolution instrumentation, including non-contact displacement measurements. Results demonstrate that substantial downdrag forces can develop at relatively low levels of excess pore pressure. Pile performance was found to depend critically on embedment depth, tip resistance reduction, and the interaction between shaking-induced and post-shaking mechanisms. Building on these insights, an enhanced load-transfer modeling framework (TzQzLiq) was developed and validated against centrifuge data, enabling displacement-based design that explicitly accounts for the temporal evolution of soil-pile interaction. The proposed framework provides a rational alternative to conventional force-based approaches, offering improved prediction of settlement and more efficient pile design strategies in liquefiable ground conditions.