Ph.D. Final Defense

MEASURING SOIL PRESSURES ON A RIGID FOUNDATION ELEMENT DUE TO LIQUEFACTION-INDUCED LATERAL SPREADING

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Ground movements due to earthquake-induced lateral spreading are a major source of damage and economic loss from earthquakes for various types of structures, including pile foundations. While a relatively large amount of work has been completed regarding lateral loads imposed on flexible foundation elements, such as small diameter pile foundations, there is less work pertaining to lateral pressures of larger, more rigid, foundation elements. Rigid foundations are becoming more commonly used in supporting large bridges.

Fourteen centrifuge tests were conducted at the NEES facility at Rensselaer Polytechnic Institute (RPI) to investigate the lateral spreading-induced pressures on a relatively large deep foundation (caisson) and to observe the related ground movement of a lateral spread. Obtaining accurate pressures in soils is perhaps one of the most challenging prospects in geotechnics. To attempt these measurements, tactile pressure sensors were used in this series of tests because they are very thin and flexible; solving some of the common problems of potential arching and poor compliance issues found in conventional earth pressure cells. However, even with the benefits of these pressure sensors, challenges were encountered with their use under these conditions. For example, the raw dynamic measurements were found to be unreliable. Other problems were identified as well regarding their use. A separate testing program was undertaken to better observe the behavior of the tactile pressure sensors and to seek appropriate methods to recover useable dynamic pressure data from the raw pressure sensors output. The approach used to recover the pressure sensor data included developing depth-dependent correction factors. The correction factors were determined using a set of centrifuge tests specifically designed to observe the response of the pressure sensors, along with parallel pore water pressure transducer records in hydrostatic and hydrodynamic testing conditions. Although more work needs to be completed in characterizing the behavior of these pressure sensors, the measurements obtained offer insight about the general pressure magnitudes and distributions acting on the caisson during lateral spreading.

During lateral spreading, as the ground moved toward the unprotected foundation, a passive wedge of soil formed upslope of the model foundation. The size of this passive wedge controls the net pressure exerted on the deep foundation element. The passive wedge was observed directly by monitoring incremental surface displacements during lateral spreading and by examining ground movement patterns with depth in the centrifuge tests. From these experiments, parameters were extracted (equivalent friction angle, ϕ_{eq}; passive wedge depth, h; and pore water pressure ratio, r_u; all occurring at time steps of maximum pressure on the caisson). These parameters help describe the size and shape of the passive wedge and, ultimately, the lateral pressure imposed on the caisson. Using these parameters, an analytical approach to modeling the results-a newly developed modified Broms method-was developed to provide a simple method for estimating lateral pressures under these conditions. This method also estimates a lateral pressure distribution shape consistent with the observed pressure distribution.

The efficacy of ground deflection walls positioned upslope of the model caisson to reducing pressures on the caisson was also explored. The overall ground displacements were significantly greater for the protected caisson tests (those with the ground deflection walls) than for the unprotected caisson tests, suggesting that the laterally-spreading soil was readily advancing around the deflection walls relatively unimpeded. Additionally, the lateral pressures generated on the upslope face of the protected caissons were substantially lower than those of the unprotected caissons. This research indicates that ground deflection walls may be installed for seismic retrofits of existing bridges, while large diameter foundations may be constructed with a diamond or circular shape to mitigate the consequences of lateral spreading for new construction applications.

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