ABSTRACT

Underground construction plays a major role in the future of urban development worldwide. It eases congestion pressure arising from land scarcity and often utilised for critical lifelines such as subway train and highway tunnels, gas, electrical, water and sewerage pipelines. Historical and recent earthquake events have proven the susceptibility of these underground structures to damage. These underground structures passing through liquefiable soil deposits are prone to floatation due to their lower unit weight compared to the surrounding saturated soil. This research seeks to investigate the floatation mechanism of a rigid underground structure in liquefiable soil. The aim of this research is to mitigate such seismic risk which could bring cities to a standstill following a major earthquake event, should the underground structures suffer damage due to floatation.

Centrifuge tests conducted at the Schofield Centre of the University of Cambridge have established the risk of buoyant circular underground structures in loose saturated sands to floatation. An underground structure experiences an uplift force due to its buoyancy. Conversely, the overlying soil weight and the shear resistance developed in the soil inhibit the floatation. In the event of liquefaction, the soil loses most of its shear strength and the structure may float if there is a net uplift force. An additional force component is introduced to account for the excess pore pressure at the invert half of the circular structure. The force equilibrium is then considered to predict the uplift displacement of underground structures with a modified Newmark's approach. The prediction corresponds well with experimental uplift displacements in various conditions such as different peak earthquake acceleration, frequency and duration, different masses and diameters of structure, as well as different relative densities, types of sands and hydraulic conductivities of sand. The influence of the buried depth and diameter of the structure are also studied and depth-effect and diametereffect ratios are developed. Similarly, the type of sand, hydraulic conductivity and relative density of the soil can affect the uplift response of the structure significantly. The influence of the soil-structure interaction on adjacent excess pore pressure was also investigated accompanied with Particle Image Velocimetry (PIV) analyses. With better understanding of the floatation mechanism of the structure, a novel remediation method against floatation is developed and has shown to be effective in mitigating the floatation of underground structures in liquefiable soil deposits.

Keywords: underground structures, floatation, liquefaction, centrifuge tests, force equilibrium, PIV