

Abstract

Historical and recent earthquakes often remind the need for taking precautions against earthquake-induced liquefaction damage that structures on shallow foundations can suffer. Air injection technique has the potential to improve the soil supporting new and existing structures. There is, however, little research on its application and performance beneath existing shallow foundations. The aim of this research was to provide a comprehensive view of the air injection technique by conducting well-controlled dynamic centrifuge and 1-g shaking table tests, along with static soil column experiments in the laboratory.

Detailed analysis of the test results highlighted that air injection was an effective way of minimising the soil-softening and loss of shear stiffness associated with earthquake-induced liquefaction. A decreasing trend in the magnitude of excess pore pressures and foundation settlements was observed with decreasing degree of saturation. Air injection technique was also found to perform better under increased confining stresses.

Injecting air in a controlled manner (e.g. applying low air injection rate and pressure) was shown to be crucial for the safety of foundations. A wider and more uniformly desaturated zone was achieved with increasing air injection pressure, but which concurrently increased the settlements that shallow foundations experienced. It was also found that most of the air could remain entrapped in partially saturated soil under different simulated field conditions for a long period of time, which indicated the long-term reliability of the mitigation accomplished.

Particle image velocimetry was utilised to identify deformation mechanisms that develop underneath and in the ground surrounding shallow foundations. It was shown that foundations resting on saturated soil settled excessively. Foundation settlements were predominantly driven by deviatoric strains, and a bearing capacity failure mechanism did form. When air was injected into saturated soil, air reduced the build-up of excess pore pressures as it contracted during dynamic loading but increased soil compressibility. Deviatoric strain-induced deformations significantly reduced, which resulted in much smaller settlements. The observed settlements were principally caused by volumetric strains that arose from increased soil compressibility. Given the depth of liquefaction reduced significantly for air-injected partially saturated soil, a complete bearing capacity failure mechanism could not occur. The lower the degree of saturation, the shallower and more localised the deformations were observed.