

# Abstract

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Pile foundations are typically used to support engineering structures where the surface soil is of poor quality, and are a common foundation solution in areas of high risk of seismic liquefaction. During strong earthquakes these foundations must resist both inertial demands from the motion of the superstructure and foundation, and kinematic demands from the liquefying soil. Lateral spreading, a phenomenon associated with seismic soil liquefaction, can impose particularly large kinematic demands on pile foundations through the gross horizontal movement of liquefied soil, and widespread damage to pile foundations has been observed after many strong earthquakes (including the 2010-2011 Christchurch, New Zealand earthquakes) in areas where extensive liquefaction and lateral spreading occurred.

Our understanding of the complex interaction between the laterally spreading soil, foundation, and superstructure has advanced considerably in the last 30-40 years, yet the design of pile foundations in laterally spreading soil is still affected by uncertainty. A better understanding of the implications of the assumptions underlying the design of pile foundations in laterally spreading soil is necessary for consistent and reliable design, and is the focus of this research. Dynamic centrifuge modelling of small pile groups is the primary method used to explore the effects of pile tip and cap fixity, lateral pile group effects, and inelastic pile deformations on the foundation response. Post-earthquake reconnaissance from the 2010-2011 Christchurch earthquakes had a formative influence on the design of the experimental programme.

Across the suite of centrifuge tests several different foundation response mechanisms were observed, the dominant mechanism being affected by the pile tip fixity conditions and the pile cap restraint. For all mechanisms the coupled vertical and horizontal displacement of the foundation was a critical aspect of its response, questioning the validity of ignoring vertical components of soil-pile group interaction in lateral spreading analyses. Similarly, pile tip displacements, pore pressure communication between the soil layers, and softening of the bearing soil were found to be important for all of the foundation response mechanisms encountered. Lateral pile interaction effects in the laterally spreading and base soil layers vary over the course of a cycle of strong shaking, over the duration of an earthquake, and between the different response mechanisms. However this variation of lateral interaction effects appears to be controlled by the relative magnitude of cyclic foundation displacement as compared to the rate of accumulation of permanent relative soil-pile deformation.