Research Project Highlight

Liquefaction Triggering and Effects at Silty Soil Sites

Project # NCTRJ00118

Principal Investigator
Jonathan D. Bray, Faculty Chair in Earthquake Engineering Excellence, Professor of Civil Engineering, UC Berkeley

Research Team
Daniel Hutabarat, Graduate Student Researcher, UC Berkeley

Start-End Dates:
1/1/2018-12/31/2019

Abstract
Simplified liquefaction triggering procedures and post-liquefaction settlement procedures provide useful insights, but they cannot explain the different levels of liquefaction-induced structural damage during the 2010–2011 Canterbury earthquake sequence. It is extremely rare to have the opportunity to learn how the same ground and structures responded to several significant earthquakes that delivered different intensities and durations of strong shaking. The well-documented performance of land and structures in Christchurch, with the extensive suite of ground-motion recordings and the comprehensive subsurface investigation program, provide an exceptional opportunity to advance our understanding of the liquefaction of silty soil deposits.

The primary research tasks are to investigate, characterize, and model the seismic performance of silty soil sites. At the start of the project, we will investigate the geologic conditions of all 55 NGL-NZ sites. We will then focus on sites that conventional procedures indicate should have liquefied, but field observations indicate did not liquefy. It is hypothesized that a common set of discriminating geologic depositional environmental factors can be identified at sites that did not manifest liquefaction. It is also hypothesized that an assessment of the soil–water system response of stratified soil deposits is required to capture the observed cases of no liquefaction manifestation. *PM4Sand* has just recently been implemented in OpenSees. It will be employed to perform numerical simulations that capture the nonlinear, effective stress response of stratified silty soil deposits to develop insights regarding key mechanisms and probable reasons for the lack of manifestations of liquefaction at sites that simplified procedures indicate should have liquefied. The *PM4Sand* soil model will be exercised extensively initially to ensure its implementation in Open*Sees* is providing reliable results. It is hypothesized that the hydraulic response of the soil–water system will be a key issue to explore and to describe. Lastly, we will develop a set of design guidelines for evaluating liquefaction triggering and its consequences at silty soil sites.

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Deliverables

- Identify the key characteristics of 55 well-documented sites in Christchurch, New Zealand, that did or did not produce surface manifestations of liquefaction during the 2010–2011 Canterbury earthquake sequence.
- Provide guidance to Caltrans engineers for adjusting current state-of-the-art liquefaction triggering procedures for silty soil sites.

Research Impact

Learning from observations after design-level earthquakes is invaluable to advancing understanding in earthquake engineering. Investigating the occurrence or nonoccurrence of liquefaction of stratified deposits of silty and sandy soils and evaluating the effects of liquefaction on bridges and lifelines provide invaluable information that will serve as benchmarks to our understanding of soil liquefaction. The geologic data can be used to improve current empirical liquefaction triggering procedures and their consequential effects. Most of the liquefaction data currently available relates to sandy soils, so careful examination of silty soil sites will assist greatly in broadening the applicability of design methods.

The over-prediction of liquefaction triggering by current procedures at silty soil sites in Christchurch appears to be due to their inability to capture the seismic performance of stratified silty soil deposits. The empirical database used to develop these procedures consists primarily of liquefaction triggering data from sand sites. Conservatism of the empirical liquefaction triggering procedures also contributes to the over-prediction of liquefaction. Engineers are currently faced with a dilemma: How can the prediction of liquefaction in these silty soils using established liquefaction triggering procedures be reconciled with the contradictory observations that surface manifestations of liquefaction were not observed after intense shaking from the Canterbury, New Zealand, earthquakes? This project will develop insights that will enable engineers to adjust state-of-the-art liquefaction procedures to address the discrepancy of their over-prediction of liquefaction triggering with the field observations that stratified silty sites of particular characteristics do not manifest liquefaction and damage bridge foundations.

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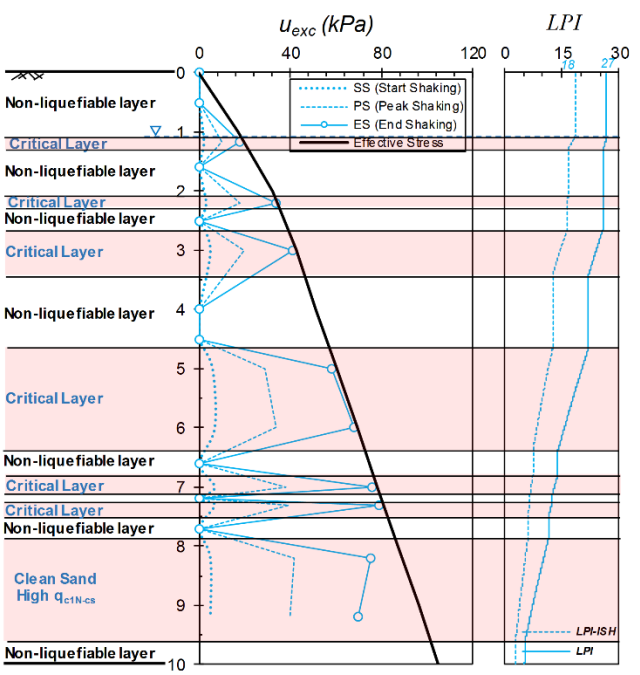
Project Image



(a) Gainsborough Site, New Zealand: Highly stratified deposit of silty soil with discontinuous, thin critical layers; high Liquefaction Potential Index (LPI) calculated, yet no manifestations of liquefaction observed after the 2011 Christchurch earthquake.

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