Evaluating Liquefaction Potential of "Challenging" Soil Sites

Student: Kaleigh M. Yost

Faculty Advisors: Russell Green (rugreen@vt.edu)

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Project Background

This research is motivated by the consistent mispredictions of the severity of surficial liquefaction manifestation at challenging soil sites (e.g. sandy soil deposits with interbedded silt and clay layers) during the 2010-2011 Canterbury, New Zealand earthquake sequence (CES), and the prevalence of analogous sites in regions of the US and worldwide where the costs of mitigating the risk of liquefaction are exorbitant. The hypothesis is that an understanding of the geomorphological controls on liquefaction triggering and the severity of surficial liquefaction manifestation, determined by novel in-situ testing at challenging soil sites, will allow the source of mispredictions of liquefaction severity to be identified and provide a basis for overcoming the shortcomings in the current liquefaction hazard procedures. "Geo-slicing" will be performed at a suite of case history sites in New Zealand to allow us to identify whether the shortcomings in the current liquefaction triggering procedures to accurately predict the severity of surficial liquefaction manifestations at sites of certain geomorphologies relates to the prediction of liquefaction triggering at depth or the prediction of cumulative liquefaction response of the entire profile. The third generation of the Vision Cone Penetrometer (VisCPT) will be brought into production mode and utilized as a practical means of characterizing challenging soil sites, where thin silt and clay layers are often "missed" by the conventional Cone Penetration Testing (CPT).

Project Objectives

The objectives of this study are:

1. Advance the state of knowledge and practice in liquefaction damage assessment of "challenging" soil sites (e.g. sandy soil deposits with interbedded silt and clay layers)
2. Understand the geomorphological controls on liquefaction triggering and severity of liquefaction manifestation and challenging soil sites

Research Plan

A list of proposed research tasks and progress is provided below:

1. Site Selection
    a. ~40 sites will be selected and grouped into two categories: sites at which both geo-slicing and VisCPT will be performed, and sites where only VisCPT will be performed (~20 sites in each group).
    b. Sites will be selected based on stratigraphies and geomorphologic controls determined from existing data.
    c. Sites at which there are and are not disparities in the predicted versus observed liquefaction response will be included.
2. Bringing the 3rd Generation VisCPT into Production Mode
    a. The new VisCPT probe will be integrated with the University of Michigan's penetration and data acquisition systems.

   b. Calibration chamber tests will be performed at Virginia Tech in one of the largest geotechnical calibration chambers in the US. Test specimens will be prepared that have the characteristics of challenging soil sites in Christchurch.
   c. Correction factors will be developed for the influence of thin interbedded silt and clay layers on the measured CPT tip resistance in the sand layers.
   d. The minimum thickness of a finer-sized (silt or clay) particle layer that the VisCPT can accurately detect will be determined.
3. Field and Laboratory Testing
   a. Geo-slicing and VisCPT will be performed at ~20 sites, and VisCPT will be performed at an additional ~20 sites around New Zealand.
   b. Samples from geo-slicing will be obtained for laboratory index testing.
   c. The stratigraphy determined from the geo-slicing and VisCPT and the manifestation of liquefaction features at depth (or lack thereof) will be correlated with the depositional environment of the deposits and the in-situ test metrics from other available geotechnical tests at the site.
   d. Geologic and geomorphic controls on the severity of manifestation of liquefaction will be documented and used to place the sites into groups.
4. Data Analysis
   a. Receiver Operator Characteristic (ROC) analyses will be used to establish threshold index values (e.g. LPI) corresponding to different severities of surficial liquefaction manifestations at challenging soil sites having common characteristics.
   b. Case histories from additional challenging soil sites will be obtained from literature where more conventional in-situ tests were performed and information about the depositional environment and geomorphological controls is known.
5. Develop Procedure to Assess Liquefaction Damage Potential at Challenging Soil Sites
   a. The proposed procedure can be implemented using different levels of rigor for characterizing the site of interest, depending on project needs and resources.
   b. When possible, VisCPT is used to determine the profile stratigraphy to include corrected CPT tip resistances. The recommended density of the soundings to develop an understanding of the site's geomorphological controls on liquefaction will be based on rules of thumb for specific depositional environments developed during Task 3.
   c. Once the site is characterized, threshold index values (e.g. LPI) that correspond to different severities of surficial liquefaction manifestation developed in Task 4 are selected for the site of interest.
   d. The remaining steps in the procedure are the same as those commonly used to evaluate liquefaction potential at a site. The procedure can be used within deterministic or probabilistic frameworks.

Project Deliverables

1. Database of detailed liquefaction case histories of challenging soil profiles including:
   a. Depositional environment and associated geomorphological controls
   b. Mapping of geologic profile including stratigraphies and soil properties
   c. Evidence of liquefaction (or lack thereof) at depth
2. Readily implementable procedure that practitioners can use to assess the liquefaction hazard of challenging soil sites