Research Project Highlight

Towards Multi-Tier Modeling of Liquefaction Impacts on Transportation Infrastructure

Project #1132-NCTRBM

Principal Investigator
Brett Maurer, Assistant Professor, University of Washington

Research Team
Mertcan Geyin, Graduate Student Researcher, University of Washington
Alex Baird, Graduate Student Researcher, University of Washington

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Abstract
State-of-practice approaches for predicting soil liquefaction at the regional-scale (i.e., commensurate with distributed transportation infrastructure) have traditionally relied on (a) geology maps that are typically too general to be accurate at site-specific scales; and/or (b) *in situ* geotechnical tests that are typically too costly to be feasible over large areal extents. It thus remains a persistent challenge to assess regional liquefaction hazards in a manner that is both accurate and inexpensive. By corollary, a still more difficult challenge is to predict the damage and loss incurred by transportation infrastructure as a result of liquefaction. Ultimately, infrastructure planners and owners must make decisions based on these downstream impacts, not on probabilities of liquefaction occurrence. Meanwhile, liquefaction-prediction models based on freely available geospatial data have recently been proposed. In contrast to conventional geotechnical methods, "geospatial" models can predict liquefaction rapidly and inexpensively at infinitely many locations anywhere in the world. The research team has performed a preliminary test of liquefaction models based on geospatial versus geotechnical data utilizing ~10,000 case studies from the Canterbury, New Zealand, earthquakes. Two state-of-practice CPT-based geotechnical models were tested against the seminal geospatial model of Zhu et al. [2017]. Model efficacy was assessed via receiver-operating-characteristic (ROC) analysis, as shown in Figure 1(a), which measures the rates of true- and false-positive predictions. The area under a ROC curve (*AUC*) was used to quantify and compare model efficacy. As shown in Figure 1(b), the geospatial model performed remarkably well, especially considering its relative cost and simplicity. These provocative findings support the potential of this PEER Seed Project, which aims to extend geospatial modeling to predict damage and loss within performance-based earthquake engineering (PBEE) frameworks. In particular, predictive tools may be developed for pavements, bridges, pipelines, and structures on shallow foundations. This is made possible, in part, by the unprecedented infrastructure-performance data resulting from the Canterbury earthquakes, which includes damage and loss-assessments for ~80,000 infrastructure assets.

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Deliverables
The results of this Seed Project will be disseminated via a PEER report, journal papers, and conference presentations. These publications will describe the development and application of PBEE-compatible tools for predicting liquefaction impacts on transportation infrastructure using freely-available input data. The value of these products is further described in the Research Impact Statement.

Research Impact
The PBEE-compatible tools resulting from this project will allow for the downstream impacts of soil liquefaction to be rapidly and probabilistically predicted at no cost. Potential applications include: (a) regional loss estimation and disaster simulation; (b) city planning and policy development; (c) emergency response; (d) post-event reconnaissance (e.g., to rapidly identify infrastructure with possible damage, thus maximizing the efficiency of field reconnaissance); and (e) areas that lack geotechnical testing. Beyond these immediate impacts, the research could ultimately inform an ensemble-modelling approach by which engineers can statistically coalesce data of diverse origins and scales to predict liquefaction impacts, thereby exploiting all available information to the fullest extent possible. In moving towards this long-term goal, a first-order approach is critical for complimenting methods that are more advanced but spatially-constrained by economics (e.g., methods based on *in situ* geotechnical tests or effective-stress numerical analyses). As part of this Seed Project, the PBEE application of the developed tools will be demonstrated for locations within PEER's geographic domain. Candidate locations include San Francisco, California; Santa Monica, California; Eureka, California; and Seattle, Washington, among others.

References
Zhu, J., Baise L.G., Thompson E.M. (2017). An updated geospatial liquefaction model for global application, *Bull. Seismol. Soc. Am*., 107 (3): 1365–1385.

Project Image

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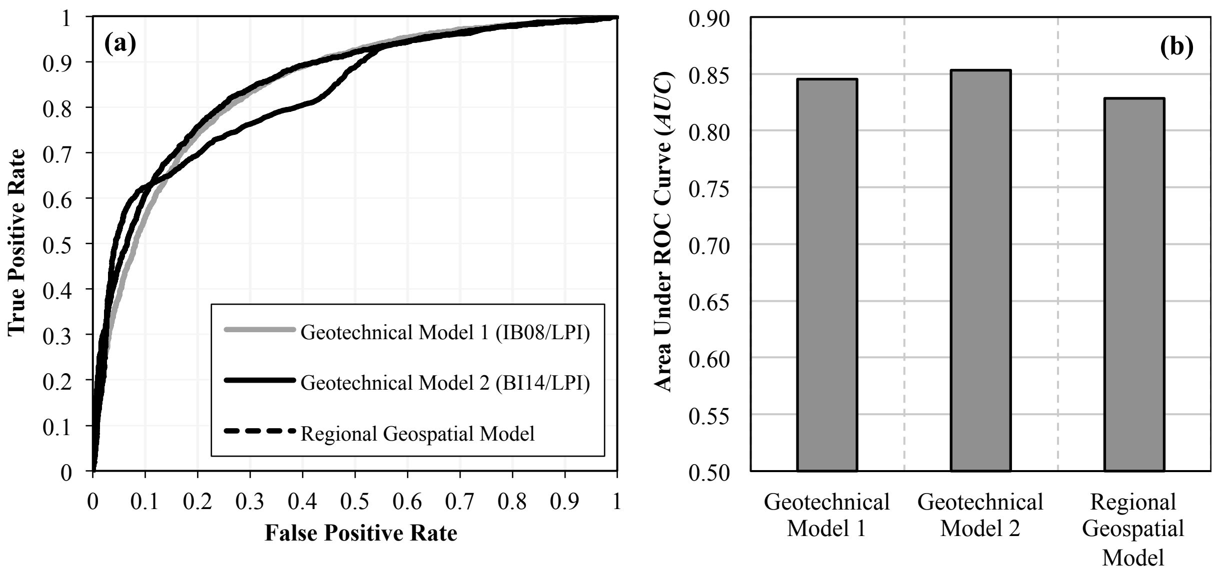

Figure 1. (a) Receiver operating characteristic (ROC) analysis of liquefaction prediction-models based on geospatial vs. geotechnical (CPT) data; and (b) summary of model performance, as quantified by the area under the ROC curve (*AUC*).

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