

Energy-based Liquefaction Evaluation Procedure



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Project Background

Soil liquefaction has been shown to cause significant damage to infrastructure during past earthquakes, such as earthquakes in Niigata, Japan (1964) and Christchurch, New Zealand (2010-2011). Several liquefaction evaluation procedures have been developed to estimate the probability of or factor of safety against liquefaction. This is important to better prepare for and mitigate potential liquefaction damage in future earthquakes. One of the more popular methods to evaluate liquefaction potential of a given site is the stress-based method, which uses in situ test indices such as normalized SPT blow count ($N_{1,60cs}$), CPT cone tip resistance (q_{c1Ncs}), or shear-wave velocity (V_{s1}) to estimate soil resistance to liquefaction. This method is semi-empirical and is based on a database of liquefaction/no-liquefaction case histories. Unfortunately, the applicability of this method beyond the limits of the case history database is uncertain and refining its results to match site-specific soil conditions via laboratory testing is difficult and expensive.

An alternative approach to evaluating liquefaction potential is the energy-based procedure. This procedure is based on a macro-level, low cycle fatigue theory and uses dissipated energy as its damage metric. The purpose of this research is to develop a new procedure to evaluate liquefaction potential using the energy-based approach. This energy-based approach will not require additional information compared to the stress-based approach at its most basic level, and yet can be scaled to match the complexity of any project. For example, laboratory testing can be performed relatively easily to refine the estimate of liquefaction resistance of a given soil rather than using an average relationship representing many soil types.

The proposed research will help minimize losses from earthquakes by improving current methods of liquefaction evaluation. Particularly, the energy-based approach can be used to confidently evaluate liquefaction hazard in areas that are underrepresented in the current liquefaction case history database (e.g., central eastern United States) and/or for non-seismic sources of vibration (e.g., vibrocompaction, induced seismicity).

Project Objectives

The principal objectives of this research and the corresponding benefits are listed below:

1. Develop an energy-based procedure for evaluation of liquefaction potential. The benefit of using an energy-based approach is that it may be applicable beyond the limitations of the liquefaction case history database.
2. Present the energy-based procedure in a format that is familiar to those currently using other liquefaction evaluation procedures such as the stress-based method. The benefit

of presenting the energy-based procedure in such a format is that it may be more readily understood and adopted.

Research Plan and Progress

The research plan tasks are listed below along with my progress (*in italics*) to date:

1. Assemble liquefaction/non-liquefaction case history database (*Completed*)
2. Develop number-of-equivalent cycles correlation using low cycle fatigue theory (*Completed*)
3. Compute dissipated energy for each of the case histories (*Completed*)
4. Determine a calibration parameter from laboratory study to reconcile laboratory results and field case histories, if necessary (*Many cyclic simple shear tests have already been performed, and we are analyzing our own test results combined with data from other research programs.*)
5. Develop liquefaction resistance curves using Bayesian model assessment techniques (*We have developed preliminary resistance curves based on case history databases with CPT, SPT, and V_s data*)

The work remaining involves refining the correlations used to estimate dissipated energy for field conditions using simplified methods and reconciling the field liquefaction case histories with the results of our laboratory tests.