Research Project Highlight

Advancing the Practice of Cyclic Softening Assessments of Silts and Clays

TSRP Topic: G1 - Triggering criteria

Principal Investigator
Armin W. Stuedlein, Oregon State University

Research Team
Ali Dadashiserej, Graduate Student

Start-End Dates:
9/1/2021-8/31/2022

Abstract
Critical transportation infrastructure networks are interwoven within weak surficial soils that pose significant seismic hazards. Compared to our understanding of basic liquefaction triggering of coarse-grained soils, the understanding of the liquefaction and cyclic softening susceptibility, triggering, and consequences of low and medium plasticity silts and clays remains somewhat poor. A simplified method for the evaluation of cyclic softening of plastic soils compatible with that of granular soils has been proposed and could be readily implemented within a performance-based earthquake engineering (PBEE) framework; however, the amount of data available to constrain the reliability of the approach is wholly insufficient to provide significant confidence in its use and application beyond the soils used as the basis for the method. The goals of this project are to: (1) add significantly to the available data by leveraging ongoing parallel research projects that have resulted in a wealth of cyclic data on silt soils, (2) interpret the existing and newly-available data within the simplified method for cyclic softening to constrain the range of anticipated cyclic resistance by the plasticity and stress history of these deposits, and (3) to develop modifications to the existing simplified method that accommodates various shear strain-based cyclic failure criteria to link the computed Factor of Safety against cyclic softening to the selected failure strain threshold and corresponding permanent displacements. These objectives will be accomplished through the development of general statistical models that capture the variation of cyclic resistance with the number of cycles of loading as function of soil plasticity and stress history.

Deliverables
A PEER report and several conference and journal papers summarizing the cyclic direct simple shear test data and corresponding/supporting laboratory characterization data, methodology, and proposed cyclic softening evaluation approach. The cyclic data will also be made publicly available on DesignSafe and the Next Generation Liquefaction database.

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Research Impact

The geotechnical profession continues to find the estimation of cyclic strength of transitional soils a challenge, with significant cost-consequences associated with improperly characterizing the seismic behavior. For example, ground improvements to mitigate liquefaction and the corresponding expense may be avoided or reduced if the cyclic behavior can be suitably characterized and quantified for those soils that are instead found to exhibit cyclic softening behavior. The development of the proposed strain-based cyclic resistance models and corresponding refinement of the simplified method will offer the profession with an improved methodology for understanding certain tradeoffs between hazard mitigation and the likelihood of deformation thresholds. Characterization of model accuracy and uncertainty will allow for future, seamless integration into a probabilistic framework (presently available for the liquefaction triggering of sands) and within a performance-based earthquake engineering (PBEE) methodology. Availability of the database underpinning this work to the public will serve to further advance research into the susceptibility, triggering, and consequences of cyclic softening.

Project Images

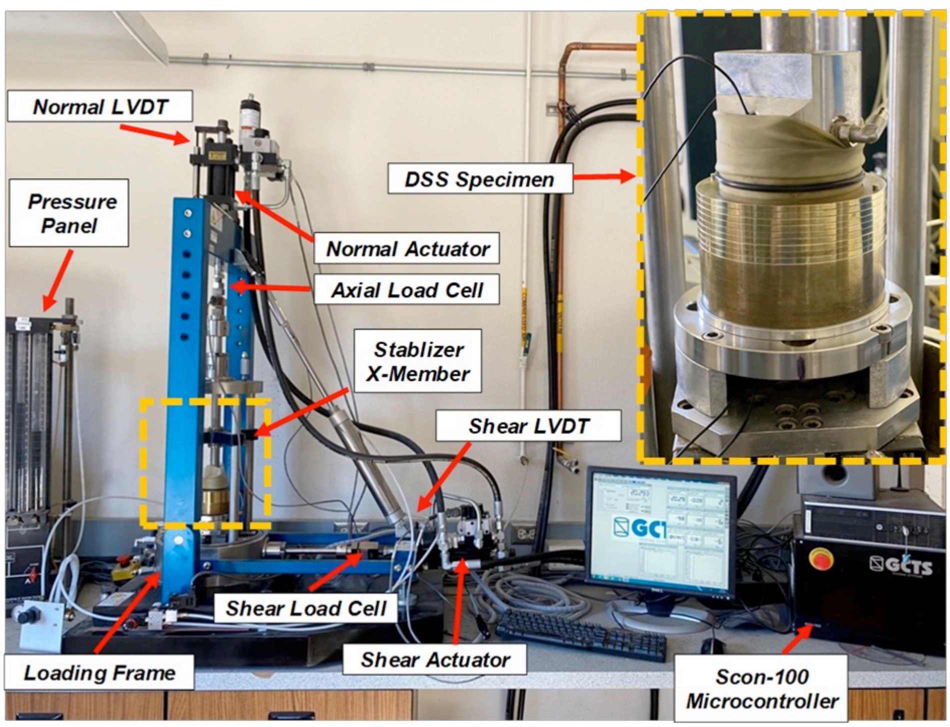

Figure 1. GCTS direct simple shear device used to quantify the cyclic and post-cyclic responses of soil specimens (internal LVDT not shown).

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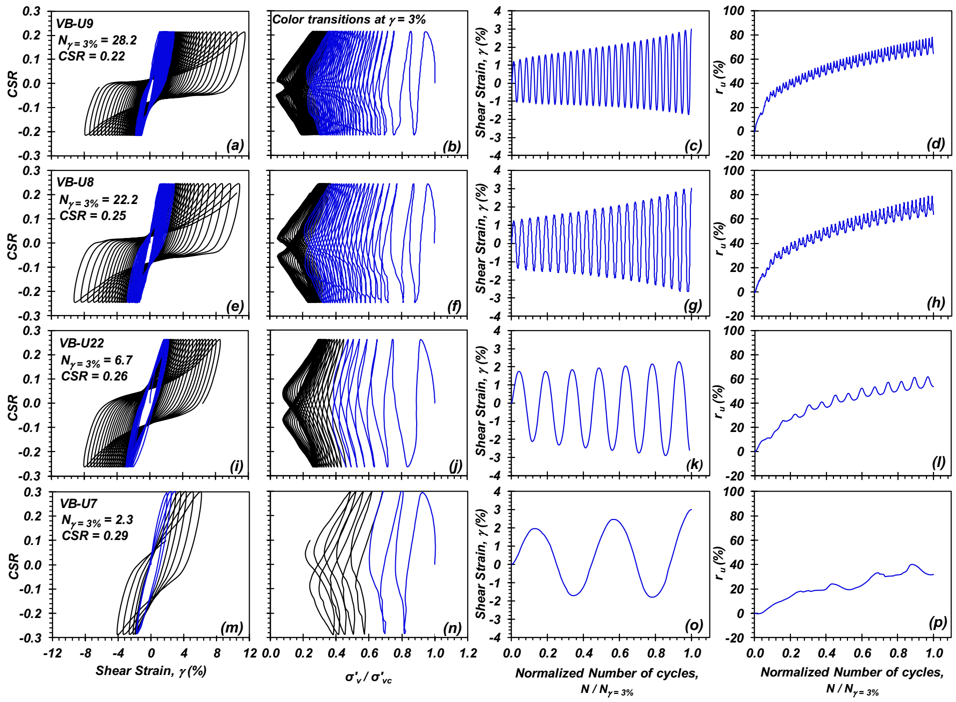

Figure 2. Example cyclic responses of low-plasticity, natural, intact Willamette Silt specimens derived from the Van Buren Bridge site, Corvallis, OR, indicating: (a, e, i, m) cyclic shear stress - shear strain hysteresis, (b, f, j, n) effective stress paths, (c, g, k, o) accumulation of shear strain, and (d, h, l, p) generation of excess pore pressure with normalized number of cycles, $N/N_{\gamma=3\%}$.

PEER Center – 325 Davis Hall, UC Berkeley, CA 94720 | peer_center@berkeley.edu