Correlations for Residual Shear Strength of Fine-Grained Soils

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Project Background

Residual shear strength is the strength of soil at large displacements and is the lowest measurable strength in a soil. In this state, clay particles are aligned on a face-to-face orientation, and there is a clearly defined failure plane that usually has a slickensided surface. Residual strength is applicable to slopes that have already failed or have been displaced a large amount; for example, residual strength is applicable to slopes that experience a large magnitude of movement due to plate tectonics.[1] Residual strength is not dependent on the stress history of the clay as shown in Figure 1.

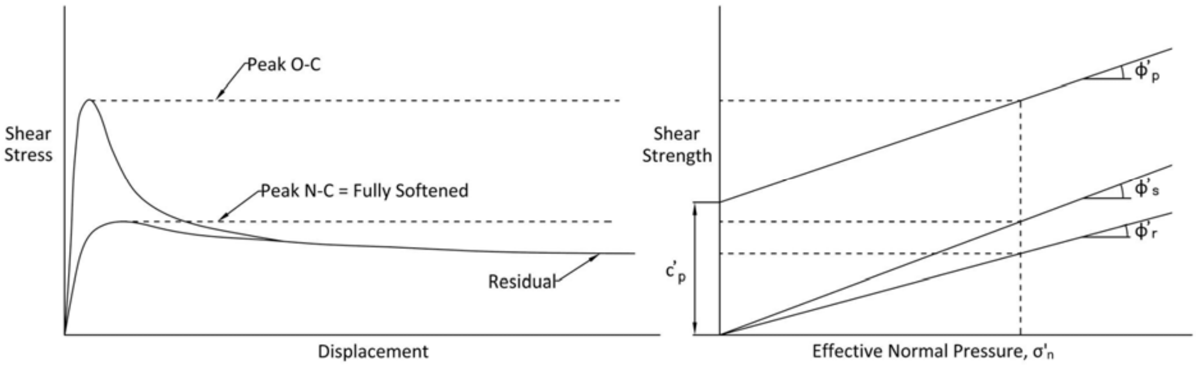

Figure 1. Residual shear strength development as a function of displacement[1]

Project Objectives

The goal of this research is to develop correlations for residual shear strength that relate clay index properties to failure envelope parameters. While determining residual shear strength in the laboratory is not complicated, the devices used are not common in most commercial laboratories and the test can take up to a week to complete. In addition, existing correlations for residual shear strength are not always supported by published data. For this reason, the data used to create the correlations will be made publicly available.

Research Plan and Progress

To develop the correlations, torsional ring shear tests are being run on diverse, fine-grained samples with plasticity indices greater than 10 from across the country and world. The torsional ring shear test was chosen to measure residual shear strength because it can apply shear displacement infinitely in a single direction and failure plane. Repeated direct shear tests can also be used, but issues arise with alignment of the clay particles, extrusion, and location of the

[1] Skempton, A.W. (1964). "Long-term stability of clay slopes." *Géotechnique*, 14(2), 77-102.

failure plane, among other things. When the shear box is reversed, the particles also switch orientation, so it is difficult to achieve true face-to-face orientation.

Remolded samples were pushed through a #40 sieve, air dried to their liquid limit, and tested at different consolidation pressures. Three different failure criteria were explored in this research: (1) linear envelope, (2) linear envelope assuming the effective cohesion intercept (c') is equal to zero, and (3) non-linear envelope. The equation used to fit the non-linear envelope was developed by Lade[2] and is presented below:

$$s = ap_a(\frac{\sigma'_N}{p_a})^b$$

Where: s is residual shear strength, p_a is atmospheric pressure, σ'_N is applied consolidation load, and a and b are curved failure envelope parameters determined for each test.

Approximately 50 unique samples have been tested so far. A correlation was created relating the plasticity index of the clay to the *a* and *b* parameters of the curved failure envelope shown in Figure 2. There is more scatter associated with the *a* parameter, but generally as plasticity index increases, parameters *a* and *b* decrease. Following Lade's equation, as parameters *a* and *b* decrease, so does the residual shear strength. A decrease in parameter *b* indicates that the failure envelope is becoming more curved.

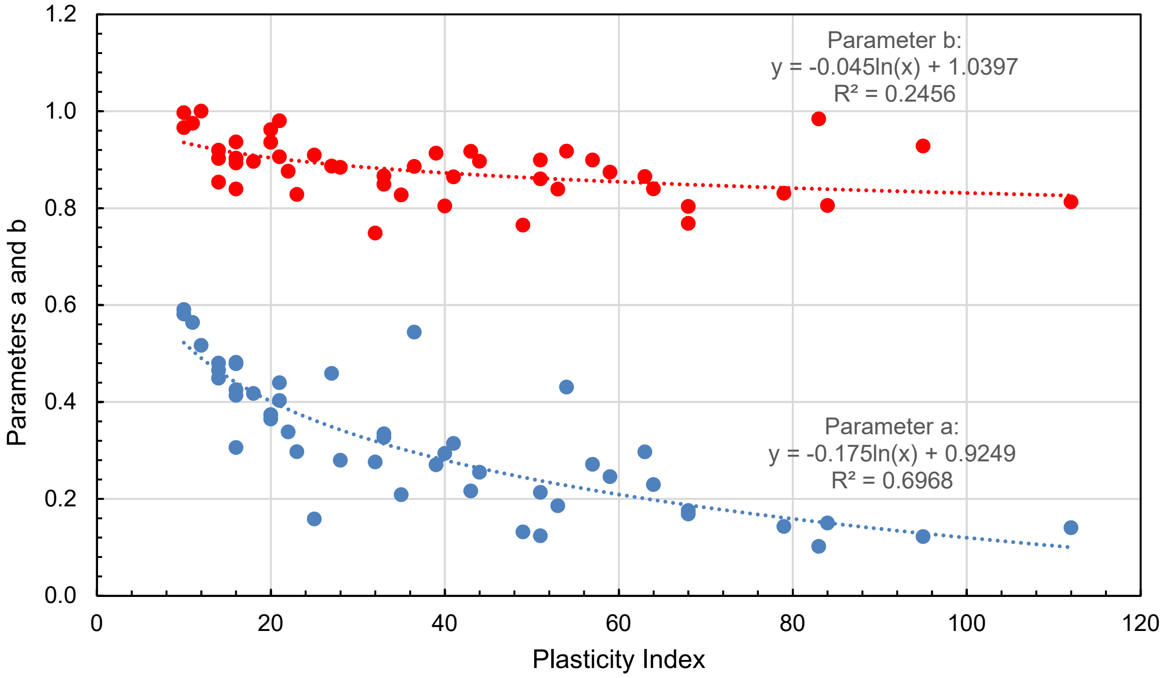

Figure 2. Correlation between clay plasticity index and curved failure envelope parameters

A correlation relating parameters *a* and *b* to plasticity index and clay-sized fraction is also being developed. In the future, more ring shear tests will be run on additional samples to refine the existing correlations as well as develop additional correlations relating *a* and *b* parameters and Mohr-Coulomb failure envelope parameters to other clay properties.

[2] Lade, P.V. (2010). "The mechanics of surficial failure in soil slopes." *Engineering Geology*, 114(1-2), 57-64.