Project Summary

Texas Department of Transportation

0-5202: Determination of Field Suction Values in High PI Clays for Various Surface Conditions and Drain Installations

Background

The Texas Department of Transportation (TxDOT) has experienced problems with recurrent failures in embankments constructed using highly plastic clays, which has led to significant maintenance costs. In response to these failures, TxDOT initiated an evaluation of the shear strength of high Plasticity Index (PI) clays under various conditions of weathering as well as back-analyses of embankment failures. Subsequent studies led to a model for evaluation of the soil shear strength as a function of time, which was based on a continuous diffusion of moisture into high PI clay slopes. Building on these previous studies, this research project has the objective of determining the effect of the passage of time on the shear strength, hydraulic characteristics, and suction profiles of high PI clays. A high PI clay from central Texas (Eagle Ford clay) was used for evaluation of hydraulic and shear strength evaluation.

What the Researchers Did

Comprehensive experimental studies were conducted as part of this project in order to evaluate the unsaturated hydraulic and shear strength properties of Eagle Ford clay. The clay was subjected to cycles of wetting and drying that are consistent with those observed in the field. Determination of the unsaturated hydraulic properties of this weathered high PI clay is necessary for prediction of suction profiles. These predicted suction profiles allowed determination of the depth of moisture fluctuations, which is expected to define the zone where the strength of the clay will be highly affected by the cycles of wetting and drying. Determination of the shear strength properties of the high PI clay was also conducted, accounting for the effect of wetting and drying. Previous research has shown that cyclic wetting and drying can, in fact, reduce the shear strength of compacted high PI clays to the fully softened shear strength. Fully softened shear strengths are applicable to first-time slides in natural and excavated slopes of stiff fissured over-consolidated material where there has not been any prior large shear displacement. The fully softened shear strength is also applicable to compacted slopes of high plasticity clays and shales exposed to wetting and drying.

The experimental component of this study regarding hydraulic characterization included a series of evaporation and infiltration experiments conducted to determine the effect of cracking on the hydraulic properties of unsaturated high PI clays. Water content and suction profiles were measured during both evaporation and infiltration stages. Analysis was conducted using the results of the experimental program to determine the effect of cracking on the hydraulic properties of the soil. Additional tests were conducted to evaluate the effect of soil placement conditions (i.e., soil conditions immediately after compaction operations).

Research Performed by:

Center for Transportation Research (CTR), The University of Texas at Austin

Research Supervisor:
Jorge G. Zornberg, CTR

Researchers:
Jennie Aguettant, CTR
Jeffrey Kuhn, CTR
Stephen Wright, CTR

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The experimental component of this study regarding shear strength characterization included series of tests on as-compacted specimens, on specimens normally consolidated from a slurry, and on specimens prepared by compacting the specimens and then subjecting them to cyclic wetting and drying. Isotropically consolidated-undrained triaxial compression tests with pore water pressure measurements were performed using Eagle Ford clay. The purpose of the tests on the specimens normally consolidated from a slurry and those subjected to cyclic wetting and drying was to determine the fully softened shear strength of Eagle Ford shale. The specimens tested in the as-compacted state served to quantify the loss in shear strength.

What They Found

Based on the results gathered as part of this study, it is concluded that failure of slopes in high PI clays is not due to a time-dependent, continuous decrease of suction (diffusion). Instead, the results of this study indicate that surficial failures in high PI clay slopes occur as a consequence of a time-dependent loss in shear strength due to the development of surface cracks, and to a discrete, season-dependent loss in suction, which is induced by precipitation.

What This Means

Suction profiles expected in high PI clays subjected to weather conditions typical of South and Central Texas were obtained in this study. These suction profiles allowed quantification of the depth of moisture fluctuation. Experimental results indicate that cyclic wetting and drying can cause a reduction in the strength of compacted high plasticity clays to the fully softened shear strength. The results of two dimensional and of infinite slope stability analyses indicate that positive pore water pressures are needed to induce failure in embankments with typical slope inclinations. Based on the results of this investigation, it is recommended that the contribution of suction not be considered in the design of clay slopes. Instead, the effective shear strength of undisturbed clay should be used below the depth of moisture fluctuation while the fully softened effective shear strength should be used within the zone of moisture fluctuations.

For More Information:
Research Engineer - Andrew Griffith, TxDOT, 512-465-7403
Project Director - Marcus Galvan, TxDOT, 512-416-2224
Research Supervisor - Jorge G. Zornberg, CTR, 512-232-3595

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Texas Department of Transportation
Research and Technology Implementation Office
P.O. Box 5080
Austin, Texas 78763-5080
512-465-7403