Integrated Full-Scale Physical Experiments and Numerical Modeling of the Performance and Rehabilitation of Highway Embankments

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Project No. 18GTLSU06

PI: Dr. Navid Jafari (LSU), Dr. Anand Puppala (UTA)

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Advancing the understanding of hydro-mechanical properties of high plasticity fine-grained soils due to wetting-drying cycles

Highway embankments consisting of high-plasticity clays will soften with time to significantly lower strengths because of wetting-drying cycles. Knowledge of the time-dependent change in hydro-mechanical properties is still lacking, since it is influenced by many factors, including: climate, extreme weather events, vegetation-soil-water interaction, erosion, formation and deepening of cracks from desiccation, and soil clay size-fraction. Because these processes are not likely to occur at the same rate everywhere, there is also considerable spatial uncertainty. As a result, this study is focused on advancing the understanding on the effects of wetting-drying cycles on hydro-mechanical properties of the high plasticity soils that comprise earthen embankments. This study will mechanistically quantify the contribution of environment, and soil factors on compacted embankments over time, using field investigation of existing embankments, laboratory-scale physical models, and numerical modeling for calibration and validation.

Background

Shear strength of compacted embankments constructed of medium to high plasticity soils start at peak strength but undergo significant strength loss over time to reach a "fully softened" state. Fig ure 1 shows the process of many cycles of wetting and drying.

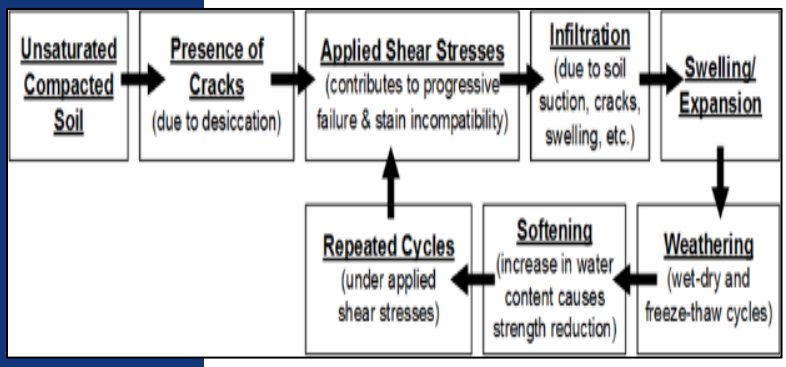

Figure 1. Development of fully softened shear strength.

In particular, desiccation and shrinking of high plasticity soil can lead to formation of fissures that allow water to infiltrate into the embankment. Upon seeping into the cracks, the water can cause the soil to swell and ultimately soften to the fully softened strength (FSS). Failures caused by rapid wetting of softened soils are usually shallow slides but can lead to major road closures. In this case, the plastic clayey soils underwent significant volumetric changes from seasonal weather changes, leading to reduced shear strengths and slope failures.

Project Summary

The objective of this study is to: (a) develop a framework that predicts which locations have a high risk of slope failure and demonstrate its functionality in the South-Central region and (b) identify cost-effective rehabilitation techniques for repairing slides. These objectives will be achieved through the following activities:

- Review of prior long-term cyclic wetting-drying experimental studies that investigated hydro-mechanical properties of high plasticity soils to establish the state-of-practice;
- Temporal field investigation of moisture conditions in highway embankments experiencing shallow failures;
- Laboratory physical modeling of wetting-drying of high plasticity soils; and
- Numerical modeling of weather and climate conditions to simulate field wetting-drying effects.

Status Update

A thorough review of the existing literature indicates that wet-dry weathering cycles have a significant impact on the mechanical properties of high plasticity clayey soils. Studies have shown that the shear strength of newly compacted clayey specimens reduces significantly when exposed to wetting and drying cycles at low confining pressures. Moreover, it has been observed that there is a significant reduction in cohesion in case of newly compacted samples subjected to wetting and drying cycles, and this result is similar to that observed for normally consolidated samples prepared from the slurry. Furthermore, the

saturated hydraulic conductivity increases by 2 to 4 orders of magnitude due to the wetting and drying cycles. This research will compare these values obtained from existing literature and assess the applicability of such results for Texas and Louisiana soils based on ongoing physical modeling of highway embankment slopes (Figure 2) and experimental results from laboratory testing.

Figure 2. Containers for measuring shear strength and moisture conditions.

Impacts

This research will advance the understanding of time-dependent changes in hydromechanical properties of high plasticity fine-grained soils due to environmental conditions. In particular, the intellectual merit of this research is to quantify the contribution of each environmental factor (precipitation intensity and duration, temperature, humidity, etc.) on the hydro-mechanical properties of compacted embankments with time. The outcome of this project will assist DOT agencies in the South-Central region by developing a predictive tool for identifying high risk zones of instability and compiling the rehabilitation methods for highway embankments. The impact will be reduced cost of maintenance by preventing failures and developing a catalog of remedial techniques.

Tran-SET

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