Transportation Consortium of South Central States

Key Points

Project Number:
17GTLSU04

Start Date:
05/08/2017

End Date:
11/08/2018

Principal Investigator(s):
Dr. Navid Jafari
Louisiana State University
Email: njafari@lsu.edu

Dr. Anand Puppala
University of Texas at Arlington
Email: anand@uta.edu

Lead Institution:
Louisiana State University

Funds Requested to UTC:
$90,983

Funding Source(s):
Tran-SET
Louisiana State University
Louisiana Transportation Research Center (LTRC)
University of Texas at Arlington

Total Project Cost:
$182,133

Prediction and Rehabilitation of Highway Embankment Slope Failures in Changing Climate

Brief Project Description

Resilience of transportation infrastructure, such as highway embankments, is critical to avoiding commuter delays and costly repairs. The majority of earth embankments across the United States, specifically in Region 6, are in marginal condition. The high-plasticity clays used by state DOTDs to construct highway embankments are subjected to many cycles of wetting and drying periods. These soils can weather, desiccate, and soften to significantly lower strengths. In addition, heavy rainfall increases the soil moisture and ultimately results in slope stability problems. As a result, highway maintenance crews continue to spend many hours fighting this problem annually. Accordingly, there is an important need (1) to develop a predictive tool for identifying high-risk locations that may fail so they can be made more resilient, and (2) to determine cost-effective methods for repairing slides.

Problem Statement

Stability analyses for highway embankments consisting of fine-grained soils have been traditionally conducted using peak strengths or some percentage of peak strength determined from standard laboratory shear strength tests on undisturbed or freshly compacted samples. Using these peak strengths and slope ratios in the range of 3H:1V (3 horizontal to 1 vertical) to 4H:1V with vertical heights of 15 to 25 feet typically results in calculated factors of safety (FOS) above the regulatory required value of 1.5. However, many of these slopes have subsequently failed, which implies the FOS is approximately unity (FOS~1.0). This disparity indicates the peak strength from standard laboratory shear strength tests are not representative of the long-term soil strength in embankment slopes.

It has been long recognized that stiff fissured clays may become “fully softened” and undergo significant strength loss over time. However, the use of full softened strength (FSS) has only come into use for compacted soil slopes in recent years. In particular, highway embankments are subjected to many cycles of wetting and drying. This extended wetting, desiccation, and weathering of embankment soil can lead to formation of fissures that allow water to infiltrate deeper into the soil than surficial wetting. Upon seeping

into the soil and cracks, the water can cause the soil to swell and ultimately soften to the FSS. Failures caused by rapid wetting of desiccated soils are referred to as slaking and usually involve shallow slides. These slides are generally shallow, occurring at depths of less than 10 ft. Additionally, the slope failures typically occur between the crown and mid-slope. Because the effects of desiccation, compaction, and over-consolidation have been removed due to many cycles of wetting, drying, and weathering, the FSS is applicable and used to reflect the long-term shear strength of highway embankments. As a result, the FSS of Louisiana and Texas soils needs to be quantified in order to develop a predictive tool for identifying high risk zones of highway embankments. Given the documented failures in Texas and Louisiana, this research project will be focused on laboratory hydro-mechanical testing in conjunction with investigating past failures to develop lessons learned and guidelines that can be implemented in the predictive framework.

Objective

The objective of this study is to (a) develop a framework that predicts which locations have a high risks of slope failure and demonstrate its functionality in Region 6; and (b) identify cost-effective rehabilitation techniques for repairing slides.

Intended Implementation of Research

Technology Transfer

A comprehensive design and maintenance guideline that provides methods for estimating full softened strength (FSS), performing stability analyses, and rehabilitating slopes will be developed for the state DOTs within the Tran-SET membership. The results will also be disseminated through journal publications.

Education, Workforce Development, and Outreach

The results from this project will produce a design and maintenance report to be used by state and local district offices and industry professionals. The results will also be disseminated using short courses, webinars, technical publications, and conference presentations. The research team will present some of the research findings in Soil Mechanics committees of AFS00 of Transportation Research Board.

Through this research, Dr. Jafari can develop a classroom demonstration that will allow students to envision the effect of soil type and weather (rain) on slope stability. He will also contribute to science fair projects that would like to test a hypothesis on different mixtures of soil, moisture, and strength.

The results from this research will also be incorporated into several courses at LSU (CE 4300 Geotechnical Engineering II, CE 4780 Coastal Geotechnics, and CE 7300 Advanced Geotechnical Engineering) as well as several courses at UTA, including CE5370 Experimental Soil Mechanics and CE5374 Ground Improvement classes. In each course, a module will be developed that the professor can use to lecture on drained shear strength of fine-grained soils. For example, the undergraduate courses will obtain a basic understanding of the three types of drained shear strength (peak, fully softened, and residual), how to measure the strengths, and how to apply the strengths to simple stability problems. The graduate level course will delve deeper into the fundamentals of shear strength, testing methods, and development of empirical correlations. They will also investigate the development of pore-water pressures from rainfall, which will be integrated with case studies to serve as an application. It is anticipated these modules can be provided to other Tran-SET universities.

Anticipated Impacts/Benefits of Implementation

State DOTDs spend significant effort (time and expenses) to repair shallow slides on highway embankments. The review of past failures and continuous field monitoring will be used to develop guidelines for rehabilitating failed slopes so that the likelihood for subsequent slides is significantly reduced. In addition, a comprehensive design and maintenance guideline that provides methods for estimating FSS, performing stability analyses, and rehabilitating slopes will be provided as it is currently not readily available in practice.

Weblinks:

- Tran-SET's website (http://transet.lsu.edu/completed-research/)
- TRB's Research in Progress (RIP) database (https://rip.trb.org/view/1466907)