Executive Summary, Research Readiness Level Assessment, and Technology Transfer

Evaluation of Critical Shear Strength of Soils in NE Based on Revised CPT

Research Objectives

1) Develop a systematic wetting technique for field soils based on the revised CPT- HPT (Hydraulic Profiling Tool) equipment.
2) Develop a CPT testing mechanism to obtain "wet-drained-fully softened strength".
3) Verify the new testing method by comparing field CPT-HPT combo test results and other reference strengths.
4) Develop a test data reduction procedure to obtain CPT-HPT-based "wet-drained-fully softened strength" and incorporate the procedure in software so that the "wet-drained-fully softened strength" can be obtained easily by the NDOT crew.

Research Benefits

1) Allow NDOT to obtain critical soil strength accurately and quickly.
2) Allow NDOT to selectively utilize materials invulnerable to substantial strength reduction.
3) Safer highways by reducing soil-related highway failure and troubles.
4) Reduced maintenance work and cost-saving by providing a more resilient highway system. Eventually, the structure designed based on this critical strength will need much less maintenance work.

Principal Investigator

Chung R. Song (P.I.)
Jongwan Eun (Co P.I.)
Seunghee Kim (Co P.I.)
University of Nebraska

NDOT Lead TAC Member

Nikolas Glennie, PE,
Geotechnical Engineer

Background

Multiple NDOT research confirmed that the back-calculated strength of soils at failed slopes in Nebraska was often much lower than the measured one in the design stage (Song et al. 2017, 2020). In some cases, the strength of soils at failure slopes was only 10% to 30% of the initial strength. Further study showed that this behavior was associated with the geological/geotechnical history of the region. And it is shared by the US, Canada and several EU (European Union) countries. This shear strength is called "wet-drained-fully softened" shear strength by researchers. The laboratory testing techniques to obtain this critical strength, however, are not standardized. Furthermore, an easily applicable field-testing technique does not exist to the knowledge of this researcher. This research proposes an innovative CPT based testing technique that can obtain this critical strength of soils in the field conveniently. The following figure shows that the CPT equipment with the capability of water injection can penetrate the ground, inject water so that surrounding soils may be wet, then conduct the CPT test. Then the wet condition is obtained, the drained condition is obtained by incorporating the piezometer readings, and the fully softened condition is obtained by taking strength parameters from the skin friction of CPT. Consequently, the "wet-undrained-fully softened" strength is obtained. This technique is much quicker for testing than the currently available laboratory technique, and therefore, the cost is more economic. This research is innovative research, however, the UNL team has years of accumulated experience in exploring soil properties with this CPT. HPT is a recently developed device that can inject water into field soils and obtain hydraulic parameters of saturated and unsaturated soils. The team has full access to these devices so that this research can progress smoothly. HPT was developed by the CPT manufacturer, and it is a system that can be easily fitted to the existing CPT system. Additionally, the CPT platform of UNL and NDOT are the same, therefore, technology transfer for findings in this research will be unquestionably smooth.

Conclusion

This study evaluated the "Fully Softened Shear Strength (FSSS)" of soils in Nebraska based on a revised Cone Penetration Test (CPT) method. FSSS is a unique strength condition that soils show substantially reduced strength during rainy seasons, eventually causing failure of slopes and other structures. The revised CPT was adapted to inject water at targeted depths, inducing controlled moisture infiltration and capturing real-time soil softening over designated intervals of 30, 60, or 90 minutes. Through tip resistance (qc) and sleeve friction (fs) measurements under "in situ" and "wet" conditions, the test effectively identified fully disturbed/low strength zones around the sleeve. Simultaneous sampling at test locations facilitated laboratory characterization of soil index properties. Subsequent direct shear testing under field-moisture conditions and 48 hour submerged conditions confirmed that high-plasticity soils exhibited similar strength loss. Conversely, lower-plasticity soils demonstrated limited magnitude of shear strength reductions. The correlation proposed by Robertson (2009) was employed to estimate undisturbed strength (su) and disturbed strength (su(d)) for the revised CPT parameters, and these correlations were compared to laboratory direct shear strength test data. Marked decreases in peak shear strength like FSSS were observed at most sites. These outcomes well aligned with Skempton's (1970) concept of fully softened shear strength, validating the measurement scheme developed in this study. Overall, the revised CPT procedure offers a reliable, efficient in situ method to evaluate fully softened shear strength, facilitating improved assessments of slope stability and soil behavior.

Executive Summary, Research Readiness Level Assessment, and Technology Transfer

Interested in finding out more?
Final report is available:
HERE

NDOT Recommendations Based Off Research Project – 2026 – RRL4

This research provided NDOT with a modified Cone Penetration Test (CPT) procedure using modified equipment for measuring fully softened shear strength of soils. The revised CPT method lends itself to evaluating critical slopes or large embankments located in areas with elevated failure potential.

The NDOT will identify a suitable location meeting these criteria for a pilot project implementation. Because the modified procedure requires specialized equipment that the NDOT does not currently own, the NDOT will coordinate with the university to borrow their equipment. Conducting the pilot project will provide the NDOT with familiarity with and an assessment of the equipment prior to committing to a future purchase.

Additionally, this project's research outcomes could be shared with the National Road Research Alliance (NRRA) or other DOTs. Broader dissemination could increase industry interest. Promote methodological consistency across agencies and potentially reduce equipment costs through expanded demand.

- *As provided by Nikolas Glennie, Lead TAC Member*

Research Readiness Level (RRL) Assessment

RRL 4

Level 4: Implementation with Follow Up
Follow up on implementation in 2 years.

Technology Transfer

Principal Investigator did not have any technology transfer for this research project.

This brief summarizes Project SPR-FY24(026)
"Evaluation of Critical Shear Strength of Soils in NE Based on Revised CPT"
Nebraska Department of Transportation Research Program