Executive Summary and Research Readiness Level Assessment

Biopolymerized Slope/Subgrade Stabilization and Advanced Field Monitoring

Research Objectives

The first objective of this project applied laboratory-proven soil modification techniques with biopolymers to field condition and confirmed their effectiveness and applicability to slopes and subgrade materials in Nebraska with climate conditions considered. Specifically, this objective was to reduce uncertainties in applying the biopolymer-based ground modification technique.

The second objective of this project provided guidance on determining optimum application parameters (such as mixing ratio, degree of compaction, water content, etc.) and rational field testing methods for evaluating field performance of these biopolymer-based soil modification techniques. This objective was achieved by comparing performance resulting from multiple different testing methods.

Research Benefits

1. Existing (problematic) slopes may be retrofitted quickly and economically.
2. New slopes may be treated by specific biopolymers at the point of construction, and the slope may be stabilized by incurring minimal extra costs.
3. The same technique may be used in stabilizing subgrade (and/or subbase) materials. With the proven long-term stability, the treated subgrade or subbase layers may provide superior performance and more extended load bearing capability compared to traditional techniques such as lime or fly-ash based stabilization.
4. Inclusively, the research results will bring in more resilient slopes and pavements.
5. Nebraska's geological history is similar to other Midwestern states. The research results, therefore, will contribute to design and construction of slopes in other states.

Background

Nebraska experiences a high number of landslides concentrated along roadside slopes. Current NDOT research project M-061 (Nebraska Specific Slope Design Manual) discovered that the strength degradation of glacial tills and weathered shales is a major cause of the landslides. Proper remediation techniques, therefore, need to be developed.

A typical remediation technique would be one that relies on external structures to support the slope, even when the strength of field soils is severely degraded. Another common option may be to fortify the soils and maintain the initial strength of field soils. Some techniques based on the first principle are earth anchors, soil nailing and berms. These techniques are usually expensive or require extra space at the downstream side of the slope. The techniques based on the second principle are grouting or field mixing and stabilizing agents, and these options are typically more economical. Due to the mineralogy of soils and weather conditions in Nebraska, most grouting liquids are not optimal techniques; many of them may exhibit either injectability issues, environmental issues, or develop premature deterioration in cold weather.

Conclusion

The slightly over consolidated glacial tills and weathered shales in Midwestern states of the USA often show substantial strength degradation after construction. This strength reduction often causes time dependent slope failures along the roadside. This study investigated the possibility of applying biopolymer based soil modification techniques to mitigate the strength reduction phenomenon of these soils. For this research, several different biopolymers were evaluated through laboratory tests, two biopolymers were selected for extensive weathering tests, then a higher-performing biopolymer, Xanthan, was applied to a test slope in Verdigre, Nebraska with heavy instrumentation. The followings are the summary of the results.

The unweathered laboratory shear strength of the weathered shales from Verdigre was improved by 20%, 30%, and 40% by mixing 0.5%, 1.5%, and 2.5% of Xanthan gum, respectively. On the other hand, the weathered shear strength of the weathered shales at Verdigre treated with 1.5% of Xanthan gum after 8 wet-freeze-thaw-dry cycles still retained 83% of the untreated unweathered ones.

A similar result was obtained for glacial tills, manifesting that the Xanthan based polymerization method may be used as a new eco-friendly method to enhance the strength of weathered shales and glacial tills in Midwestern states. The field applied Xanthan treated soils showed similar behavior to laboratory test results based on pressure meter and vane shear test results so far. However, further monitoring is required to fully verify the findings.

Principal Investigator

Chung Song (P.I.)
Yong-Rak Kim (Co P.I.)
Richard Wood (Co P.I.)
Jongwan Eun (Co P.I.)
University of Nebraska

NDOT Lead TAC Member

Nikolas Glennie, Geotechnical Engineer

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Final report is available at:
NDOT Research Website

NDOT Recommendations Based Off Research Project

NDOT will monitor the performance of biopolymer Xanthan, which was utilized on a project in Verdigre, Nebraska. The Geotechnical Engineers will use an inclinometer installed at the site to monitor the movement of the slope. Performance of the field-applied biopolymer treated soil will be followed for two years by measuring the strength and modulus of the shale through lab testing and CPT testing. Performing these tests will provide real world data, such as the strength loss of the soil due to weathering cycles for both the Xanthan treated and virgin material.

After two years the Department will analyze the strength and modulus test data and consider if using Xanthan biopolymer will be a feasible option to add to the tool box along with the geogrid, geofoam and other methods commonly used by the NDOT with the soil types investigated by this research.

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

Research Readiness Level (RRL) Assessment

RRL 3

Level 3: Development – Two Years

Research/Technology developed in an operational environment (real-world situation).

Technology Transfer

Publications

- Soroosh Amelian, Chung R. Song, Yongrak Kim, Mark Lindemann, and Layal Bitar (2022) "Weathering durability of biopolymerized shales and glacial tills", Geomechanics and Engineering.

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