Executive Summary, Research Readiness Level Assessment, and Technology Transfer

Application of Cementitious Materials and Fiber Reinforcement to Enhance Lime Stabilization for Nebraska Shale Soils

Research Objectives

The objectives of this research are to 1) Identify the effectiveness of mixing cementitious materials and fiber reinforcement to enhance lime stabilization and 2) evaluate the design properties of cementitious materials and fiber reinforcement to enhance lime stabilization for weak subgrade in Nebraska.

1) Performing extensive literature review from other DOT's cases and practices that applied to mix cementitious materials and fiber reinforcement to subgrade stabilization,
2) Evaluating geotechnical properties of weak subgrade soils (e.g., Pierre Shale) treated and non-treated with cementitious materials and fiber reinforcement,
3) Assessing environmental resistance of treated soils with freezing-thawing cycles,
4) Analyzing the performance of treated and non-treated subgrades through Large-Scale Track Wheel (LSTW) test [evaluating k value, CBR, resilient (Mr) modulus],
5) Suggesting a design practice of lime, cementitious materials, and fiber mixture. The site-specific applicability and cost-effectiveness of treated and non-treated subgrade will be identified.

Research Benefits

The proposed research will provide mixing guidelines of lime and cementitious materials or lime and fiber reinforcement stabilization with weak soils for the roadway layers. Based on the results, the site-specific applicability of lime-cement or fiber-treated subgrades will be identified. The end results of this research project will contain a performance chart of lime, cement, or fiber stabilization with the selected sets of soil conditions, aggregate types, and the types and mixing ratio of the lime and cement or fiber stabilization.

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Background

As the previous discussion, lime and cement can be mutually complementary. Lime alone has been ineffective in stabilizing several specific soils in Nebraska. In particular, lime has not been effective at stabilizing shale soils in northeast Nebraska. However, previous studies have found that by combining lime with fly ash, cement, or fiber reinforcement they can control shrinkage and swelling as well as increase strength and stiffness. This method of combining an additive with lime enhances the performance of the stabilization. However, NDOT has not tried varying proportions of additives with lime that provisions can be written, and construction practices developed for use in the field. Thus, a systematic study is warranted to help NDOT facilitate its usage for subgrade stabilization. It is needed to identify the effectiveness of mixing cementitious materials and fiber reinforcement to enhance lime stabilization and to prepare the design practice in Nebraska.

Conclusion

Lime stabilization is a widely used technique to improve weak subgrades; however, its effectiveness under freeze-thaw cycles remains a critical challenge. This study investigates the incorporation of cementitious materials and fiber to enhance the mechanical properties and environmental resistance of lime-stabilized soils under such conditions. Two types of soil, gray shale (plasticity index of 37.8) and clay soil (plasticity index of 19.0) from Nebraska, were used. Stabilization mixtures included lime dosages of 0%, 3%, and 6% by weight, combined with either 10% fly ash or 3% and 6% cement by weight, and 0% and 1% fiber. The experimental program comprised a multi-tiered approach: characterization of physical properties through geotechnical tests (e.g., particle size distribution, Atterberg limits, and standard Proctor tests), preparation of composite specimens for unconfined compressive strength (UCS) and direct shear testing, and evaluation of environmental resistance through freeze-thaw cycles (7 cycles after 14 days of curing and 12 cycles after 28 days of curing). Additionally, large-scale testing was conducted using the Large-Scale Track Wheel test to simulate field conditions. Results showed that lime and fly ash significantly reduced the plasticity index of gray shale, with less pronounced effects on clay soil. The UCS values for gray shale ranged from 61.2 to 300.7 psi for lime stabilization, 137 to 272 psi for lime and fly ash stabilization, and 129 to 490.8 psi for lime-cement stabilization. For clay soil, UCS values ranged from 68 to 149 psi for lime stabilization, 119 to 146 psi for lime and fly ash stabilization, and 204 to 379.2 psi for lime-cement stabilization. The inclusion of fiber further enhanced the shear strength parameters of the soils, particularly increasing cohesion. Cement-lime stabilization demonstrated superior UCS retention and resistance to freeze-thaw cycles for both soil types, outperforming lime alone and lime-fly ash treatments. These findings highlight the importance of incorporating cementitious materials to enhance the durability and performance of lime-stabilized soils under harsh environmental conditions.

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NDOT Recommendations Based Off Research Project – 2026 – RRL4

This research provides results and recommendations for the second stabilization of Nebraska grey shale and clay soils in conjunction with lime stabilization. The Department is particularly interested in the stabilization results for grey shale soils, which lime alone does not adequately stabilize. While the report investigates both fly ash and cement incorporation with lime, the Department is cautious of its fly ash use for soil stabilization due to possible leaching. The report recommends 6% lime-3% cement as minimum stabilizer dosage by weight for grey shale. The recommended lime/cement mix shows a variability in compressive strength, ranging from 129.0 to 490.8 psi; meanwhile, to mitigate potential cracking in concrete pavement, the NDOT targets a compressive strength of 300 psi. The research showed the benefits of mixing lime and cement for soil stabilization. For projects where lime/cement stabilization is needed, exact mix designs will be determined in-house to determine plasticity index and achieve acceptable compressive strength. After the mixes' initial use, projects will be closely monitored for multiple years to ensure the designs performance.

- *As provided by Bruce Barrett and Nikolas Glennie, Lead TAC Member*

Research Readiness Level (RRL) Assessment

RRL 4

Level 4: Implementation

Research/technology refined. Benefits of implementation will be evaluated in 3 years.

Technology Transfer

Webinars/Presentations

- Ibdah, L., Eun, J., Asif, U., Behdad, A., Feng, Y. (2025). Performance Evaluation of Lime-Stabilized Subgrade Under Large-Scale Trucking Test. University of Maryland. Presented at ACI Regional Chapter Meeting. Maryland.

Journal Papers Submitted for Review and In Progress Journal Papers and Theses

- Ibdah, L., Owusu, K., Behdad, A., & Eun, J. (2025). Effects of Freeze-Thaw Cycles on the Unconfined Compressive Strength of Lime- and Cement-Stabilized Soils. Geomechanics and Engineering, Vol. 41, No. 1, pp. 59-70.

This brief summarizes Project SPR-FY23(015)
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