Eco-Friendly Stabilization of Sulfate-Rich Expansive Soils using Geopolymers for Transportation Infrastructure

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$106,000

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Tran-SET
University of Texas at Arlington
Texas A & M University

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$212,000

Synthesize an innovative, sustainable, and eco-friendly Geopolymer suitable for stabilizing sulfate-rich expansive soils for subgrade of transportation infrastructure

When sulfate-rich expansive soils are treated with traditional calcium-based stabilizers such as lime or cement, the stabilized soil is affected by sulfate-induced heave, due to the formation of highly expansive mineral Ettringite and Thaumasite, which expand when it comes in contact with water. Since sulfate-rich soils are predominantly obtained in the South and Western U.S. and are widely used in these regions to construct pavements, alternative forms of stabilizing techniques are being sought after. In recent years, Geopolymer has received much attention as an alternative to Ordinary Portland Cement (OPC) and lime for soil stabilization, and other applications for pavements, bridges, and other transportation structures. This study will investigate the feasibility of stabilizing sulfate-rich expansive soils using Geopolymers. Effects of Geopolymer, dosage rates, and curing condition, on overall performance and structural and mechanical properties of Geopolymer-stabilized subgrade soils will be studied in order to optimize the use of Geopolymer derived from local waste and natural materials for transportation infrastructure. Volume change tests during wetting or drying and strength tests will be conducted on Geopolymer-stabilized soils that have significant sulfate concentration. Both material characterization studies related to micro to macro behavioral changes of native soils and Geopolymer-treated soils will be carried out. Sustainable, resiliency, and life cycle analysis of Geopolymer-stabilized subgrade soils rich in sulfate will also be evaluated.

Problem Statement

Currently, traditional calcium-based stabilizers such as lime at elevated pH conditions, calcium from stabilizer, and alumina and sulfate from soil react in presence of moisture to form highlyexpansive mineral Ettringite. Ettringite has 26 molecules of water and is capable of swelling by more than its volume to 137% of its original volume. These expansive minerals often cause significant damage to pavements and other transportation infrastructure. Additionally, the production of traditional stabilizer like cement is energy intensive and emits large quantity of CO2. Geopolymers as alternative to OPC constitute a family of materials consisting of covalently bonded alumino-silicates, non-crystalline networks and are generally substituted for many engineering applications due to their high strength. They have received much attention as an ecofriendly and sustainable alternative to OPC because they can be processed at room temperature inexpensively from waste materials (e.g. fly ash) or natural sources (e.g. clay), thus providing the plentiful worldwide raw material supply. More importantly, the use of Geopolymer rather than OPC can reduce CO2 emission for 44-64%. This project investigates the performance of Geopolymers in stabilizing sulfate-rich expansive soils to mitigate the 'sulfate-induced heave'. This collaborative research study formulated by Figure 1. Severe pavement distress due to sulfate-induced heave along US-67 in Texas teams from UTA (Puppala) and TAMU (Radovic) would foster the use of eco-friendly and durable novel materials for transportation infrastructure in Region 6.

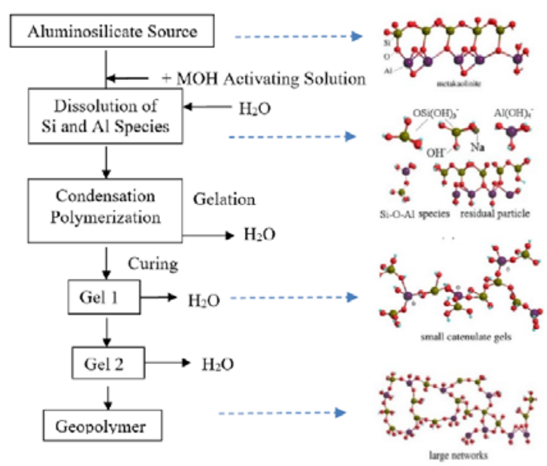

Figure 1. Geopolymerization flowchart.

Objectives

The overall objective of project is to synthesize an innovative, sustainable, and eco-friendly Geopolymer suitable for stabilizing sulfate-rich expansive soils for subgrade of transportation infrastructure in Region 6, using natural and waste materials that are abounded in the region. This research should bring major benefits in the design of distress-free pavement infrastructure in severe problematic conditions that prevail in Region 6.

More specific objectives of the proposed projects include: (a) Select composition of Geopolymer with optimum workability and mechanical properties; (b) Select appropriate sulfate-rich expansive soils in Region 6 suitable for the study; (c) Investigate the effectiveness of Geopolymers for stabilization of sulfate-rich expansive soils; (d) Provide guidance for the optimum composition of Geopolymers for stabilizing sulfate-rich soils; and (e) Implement research results and develop the workforce with the expertise in using novel technologies for soil stabilization.

Intended Implementation of Research

Workforce Development: The outcome of this research will lead to a comprehensive report that will provide design methods and guidance for Geopolymer treatments of sulfate-rich subgrade soils. The information will also be disseminated in various venues including technical publications, and conference presentations. Research team will also disseminate research findings at Transportation Research Board annual meetings. Result of this project will be also presented in at least one paper published in the peer-reviewed journal.

Outreach activities and education: Two doctoral graduate students and one postdoctoral fellow will be recruited to work on the present research tasks, and they will work with PIs at UTA and TAMU. We will develop a simple visual module to demonstrate soil stabilization technologies and testing to high school and middle school students from Texas during their summer recruitment programs at UTA and TAMU. This will contribute to the awareness and education of general public on issues related to soil stabilization in the presence of sulfate in soils. The results from this research will be incorporated into several courses at UTA including CE3343 Soil Mechanics, CE5374 Ground Improvement, CE5372 Applications of Geosynthetics, and at Texas A&M University including MSEN410 Materials processing and MSEN625 Mechanical Behavior of Materials. We develop the course modules that cover pavement subgrade stabilization designs using Geopolymers as well as sustainability assessments.

Anticipated Impacts/Benefits of Implementation

Both life cycle assessments and low carbon footprints in using Geopolymer are anticipated, which eventually lead to green transportation infrastructure.

Web Links

- TranSET's website (https://transet.lsu.edu/research-in-progress/)
- TRB's Research in Progress (RIP) database (https://rip.trb.org/View/1644241)

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

Learn More

For more information about Tran-SET, please visit our website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Mr. Christopher Melson (Tran-SET Program Manager) directly at transet@lsu.edu.

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