Transportation Consortium of South-Central States (Tran-SET)

Development of Environmentally-Friendly Stabilization Methods for Transport Infrastructure Based on Geopolymers

Highlight | Feb. 2018

Project No. 17GTTAM02

PI: Dr. Miladin Radovic (TAMU), Dr. Anand Puppala (UTA)

POP: May 2017 – November 2019

Investigating Geopolymer-based compositions for stabilizing base and subgrade foundations using natural and waste materials abound in the southwest U.S

In recent years, the use of Geopolymers has received much attention as an eco-friendly and sustainable alternative to conventional chemical additives since they can be processed at room temperatures from aqueous solutions of waste materials (e.g. fly ash) or abounded natural sources (e.g. clay). The aim of this study is to develop an innovative, sustainable, and eco-friendly solution (using Geopolymers) for stabilizing bases and subgrade foundations using natural and waste materials that are abounded in the southwest United States. The effects of Geopolymer composition, dosage rates, curing time and temperature on overall properties of Geopolymer stabilized base and subgrade materials will be studied to optimize the use of Geopolymers derived from local waste and natural materials. Both material characterization studies related to micro to macro behavioral changes are evaluated.

Problem Statement

Texas and its neighboring states have a prevalence of expansive clays, which are thought to be the primary cause of pavement distresses. As such, many low-volume roads in these areas are built on expansive clay subgrades. Expansive clays undergo volume change due to variations in its moisture content: an increase in moisture in the soil causes the clay to swell, while a decrease results in shrinkage. Swelling of expansive clay usually manifests itself in the form of heaves on pavements, while shrinking results in soil and pavement cracking (see Figure 1). These repetitive cycles of shrinking and swelling impose additional stresses to the infrastructure.

Figure 1. Paris, TX site longitudinal shrinkage cracks.

Conventionally, the swell-shrink potential of expansive clays is mitigated with the mixing of chemical additives, such as different polymers, lime and ordinary Portland cements. While chemical stabilization methods are used extensively, they are highly prone to leaching and durability issues, which make them inept as long-term solutions. One of the major disadvantages of using calcium-based stabilizers, such as lime, is that they react with sulfate minerals resulting in disintegration of soils and subsequently loss of soil strength. Furthermore, the production of additives demands high energy and generates substantial amounts of CO2. As such, there is a need for environmentally friendly and sustainable means of soil stabilization for transportation infrastructure.

Summary

Geopolymers are alumino-silicate binders which harden at ambient temperatures and in a relatively short amount of time. They can be created by curing activated solutions of various alumino-silicate sources, including natural minerals (e.g. clay) and their products (e.g. metakaoline), and waste materials (e.g. fly ash, furnace slag, etc.). Geopolymers are known for their high compressive strength and low shrinkage properties, and has been used in recent years as a sustainable alternative to ordinary Portland cements in concrete structures, including pavements, bridges, etc. Geopolymers have a much lower carbon footprint than lime or ordinary Portland cements, and is therefore more environmentally friendly than other conventional additives used for soil stabilization. This eco-friendly nature of Geopolymers over conventional chemical stabilizers prompted the present research team to investigate the feasibility of Geopolymers for effective stabilization of pavement bases, and subgrades.

An important step in the process of this research is the acquisition and characterization of base and subgrade materials commonly available in Texas for the purpose of geopolymer treatment. The three types of soil that have been acquired are: high plasticity clay (CH), low plasticity clay (CL) and poorly graded sand (SP). The soils are characterized by laboratory index soil properties ranging from water content, specific gravity, particle-size analysis, Atterberg limits, and moisture-density relationships based on American Society for Testing and Materials (ASTM) testing procedures. Different geopolymer compositions will be selected for stabilizing these soil samples, which will be determined based on the viscosity of the selected geopolymer base and workability of the mixture. The three soils will be stabilized with different geopolymers at different dosage levels to optimize durability and mechanical properties. Engineering characterization studies will be performed to evaluate the enhancement in strength, stiffness and durability of the geopolymer stabilized soils. Stabilized bases and subgrades will then be subjected to unconfined compression strength (UCS), resilience modulus, and free vertical swell and linear shrinkage bar tests. All results will be analyzed to address the improvements in engineering properties from geopolymer treatments.

This study therefore investigates the effectiveness of Geopolymers for stabilizing base and subgrade materials in Texas (see Figure 2), with the goal to optimize composition and curing conditions of Geopolymers derived from local waste and natural materials for soil stabilization. The goal is to be able to stabilize the soil with 10 percent or less by weight of geopolymers.

Figure 2. Pure geopolymer (left) sample and samples of sand (middle) and soil (right) stabilized with 10% geopolymers (by volume) after curing.

Findings

To date, the research team has conducted a literature review of soil stabilization using Geopolymers, acquired lowplasticity clay soils from around the region for base and subgrade testing materials, and finalized a procedure for making Geopolymer treated samples with different compositions and solid-to-water ratios. The research team will begin and continue comprehensive material and engineering characterization of these samples and analyze the results. Both material characterization studies related to micro to macro behavioral changes will be evaluated. Hence, as more results are obtained from different characterization techniques, composition and/or process can be tailored to improve the properties, and eventually obtain the optimal properties.

Impacts

This research will provide major benefits in the design of durable and distress free pavement infrastructure in problematic soil conditions that prevail in Texas and other southwest states, using local environmentally-friendly and sustainable materials. Improvements to both life cycle assessments and lower carbon footprints using these developed treatments are anticipated - leading to enhanced durability and more environmentally friendly infrastructure.

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.