Development of Geopolymer-Based Cement and Soil Stabilizers for Transportation Infrastructure

Investigating the long-term durability and leachability properties of geopolymer-based soil stabilizer and geopolymer cement concrete

Highlight | Jan. 2019

Project No. 18CTAM03

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

POP: March 2018 – November 2019

Geopolymer cement (GPC) has received much attention as an alternative cementitious material for soil stabilization, pavements, bridges, and other transportation structures. The increasing interest resides mostly on the fact that they can be processed at room temperatures from aqueous solutions by utilizing waste materials (e.g. fly ash) or abundant natural sources (e.g. clay) using less energy than is required to produce conventional cementitious materials. This collaborative study investigates the durability performance of various GPC structures during long-term exposure to typical service conditions faced in the South-Central region. The tests will simulate flooding and extreme rainfall conditions, to validate the use of GPC materials for transportation infrastructure. Both material characterization studies related to micro to macro behavioral changes during long-term exposure of GPC concrete and stabilized base and subgrade materials to water will be carried out as a part of this research.

Background

Currently, Ordinary Portland Cement (OPC) is the material of choice for transportation infrastructure as it has been widely used for concrete structures (pavements, bridges, etc.) and stabilization of base and subgrade materials. However, production of OPC involves large energy consumption to achieve the high temperatures that are required for reaction between clay and calcium-carbonate ($CaCO_3$). This process also results in the release of enormous amounts of carbon dioxide (CO_2), estimated to be about 5-6% of the global CO_2 emission.

Geopolymer cements (GPCs) are a family of materials consisting of covalently bonded alumino-silicates, amorphous networks and are generally substituted for many engineering applications due to their high strength. Over the last decade, GPC has been considered as an attractive alternative to OPC in reinforced concrete structures, not only because of their good mechanical properties, but also because they can prevent extensive corrosion of the reinforcement that usually take place in OPC concrete structures over an extended period. Additionally, the use of GPC rather than OPC is said to bring about a reduction in CO2 emissions by about 40-60%. Most recently, GPC has been investigated as an alternative to OPC for soil stabilization to prevent frequent failures of the pavement and other transportation infrastructure.

Project Summary

The objective of this project is to develop an innovative, sustainable, eco-friendly, and durable geopolymer cement (GPC) for transportation infrastructure in the South-Central region, more specifically for concrete structures and stabilization of base and subgrade foundation support for pavement support. To accomplish the objective, the research will focus on selecting the GPC composition with optimum workability and mechanical properties and then characterize the durability and leachability behavior of GPC under simulated weather conditions typical for the South-Central region. The research will then be implemented accordingly to the results and develop the workforce with the expertise in using novel technologies for soil stabilization. The results will also provide guidance for the optimum composition of GPCs for extended durability of concrete structures and stabilized soil.

Status Update

The project is still in the research and experimental phase. From the current results on soil stabilization, geopolymer greatly improves the shrinkage behavior of the Texan soils (see Figure 1), however, the strength is still lackluster with the best results showing 3-4 times increase from the strength of untreated soil. The team is currently conducting a comprehensive parametric study to optimize the strength of the low plasticity Texan soil to hopefully reach equal or better strength than from treating with ordinary Portland Cement. Once the parametric study has been completed, then the team will use those results as a guidance to optimize the strength high plasticity

Texan soil. The optimal compositions will then be tested for durability and leachability tests.

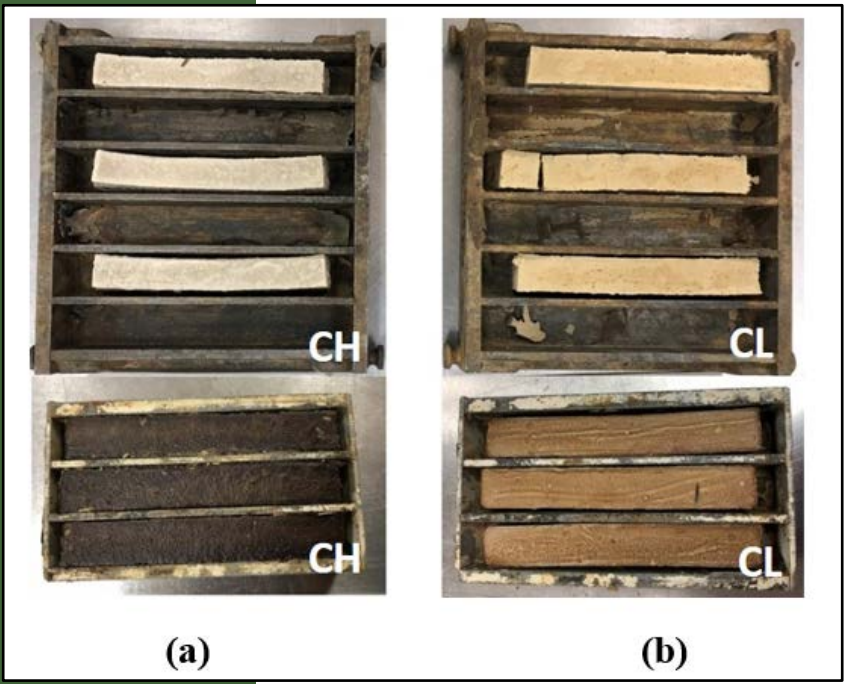

Figure 1. Shrinkage of untreated (top) and treated (bottom) samples (a) CH, (b) CL.

As for the portion on geopolymer cement (GPC) concrete, the team is currently doing a parametric study on pure GPC to optimize the strength. Once the optimal pure GPC is determined, then the team will investigate the effect of aggregate on the strength of the GPC concrete. Lastly, the study will be completed with durability and leachability tests of the GPC concrete.

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. The increase in durability and decrease in leachate formations of GPC minimize the environmental impact, which would be beneficial to all areas of Region 6.

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".

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