Soil-Recycled Aggregate-Geopolymer Road Base/Subbase Mixtures: Step Towards Sustainability

Evaluating mechanical characteristics of soil mixtures modified with recycled aggregates and geopolymer binders for pavement base and subbase layers

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Even though soil-cement mixtures provide firm support as a base material, the inherent material's shrinkage and associated environmental concerns, establishes a pressing need for substitute road base materials. One such alternate material is Geopolymer binders/cements, which represent an innovative class of "green" technology. Such materials mainly rely on industrial by-products (coal, flyash, Ricehusk/ sugarcane ashes, etc.). This study focuses on the development and evaluation of sustainable Soil-Recycled Aggregate-Geopolymer (Soil-RAG-GP) mixtures for road base and subbase layers. It is believed that the developed Geopolymer-based soil base/subbase materials will exhibit high durability, high mechanical performance, and environmentally friendly and sustainable characteristics. Effects of various mixture variables will be studied. Optimum mixtures will be selected and compared with the conventional soil-cement mixtures. Based on the results and analysis, guidelines and recommendations will be developed for its cost-effectiveness and use as a pavement base material.

Background

Soil-cement stabilized road bases provide substantial support to the overlaying hot mix asphalt (HMA) layer – reducing stresses, minimizing deflection, and providing resistance to freeze-thaw action. This base type has become cost-effective Louisiana, which has deficiency in aggregates. Hence, the Louisiana DOTD has constructed several thousand lane-miles of soil-cement bases for more than four decades. There is one drawback: soil-cement mixtures causes shrinkage cracks in the base layer, which reflects through the HMA layer. The cracks are termed as "reflective cracks" and are responsible for poor ride quality and negatively affect long-term performance. It is imperative to develop new base materials by utilizing advanced alternate cementing technologies and available recycle aggregates (RAG) to provide cost-effective solutions, such as: recycled concrete (RCA) and reclaimed asphalt pavements (RAP). One such alternate material is Geopolymer binders. Geopolymer materials represent an innovative class of "green" technology, which mainly rely on industrial by-products (coal, flyash, Ricehusk/ sugarcane ashes, etc.) to significantly reduce its carbon footprint. This study intends to utilize flyash based geopolymer binders and RAG to stabilize pavement base and subbase using the concept of geopolymerization.

Project Summary

The main goal of the study is to develop and evaluate sustainable Soil-Recycled Aggregate-Geopolymer (Soil-RAG-GP) mixtures for road base and subbase layers. It is believed that the developed "green" Geopolymer-based soil base/subbase materials will exhibit high durability, high performance, and environmentally friendly and sustainable characteristics.

In order to develop Soil-RAG-GP stabilized road base materials, several materials will be selected including various types of Class F flyashes, soil types, and activation agents (sodium hydroxide and sodium silicate). The mechanical characteristics of the Soil-RAG-GP mixtures depends on various mix constituents, such as amounts of flyash, RAG, sodium silicate and sodium hydroxide content, and the curing period and temperature. Based on various combinations of the above variables, partial factorial experimental design will be developed to minimize mechanical testing. Unconfined compressive strength, elastic and dynamic modulus, durability, and shrinkage characteristics will be evaluated using standard test procedures. In addition to mechanical testing, elemental analyses and scanning electron microscopy (SEM) micrographs will also be studied to understand the basic morphology and microstructure of Soil-RAG-GP. The mixtures will be cured at various temperatures before testing. The strength and modulus tests results will be compiled and a preliminary statistical model will be developed to relate strength with the mix variables. The model will assist in sensitivity analysis of variables and

determining the optimum/practical mix design parameters to be used in base/subbase materials.

Status Update

Unconfined compression strength (UCS) specimens were constructed using medium plastic soil, two types of Class F flyashes (FA), RCA, and alkali activators and oven cured in sealed containers at 60oC for 72-h (Figure 1).

Figure 1. UCS test specimens

Preliminary testing revealed that the UCS of soil-alkali mixtures increased with the increase in oven curing time and at 72 h the UCS plateaus with minimum rate of strength gain. Several Soil-RCA-Geopolymer mixtures were prepared with varying contents of FA (0-25%), RCA (0-25%) and Sodium Silicate (0 to 50%) in six molar sodium hydroxide solutions and tested for UCS. It was found that an increase in FA and RCA content increased the UCS and E of the Soil-RCA geopolymer mixtures for both FA types (SL and BR). FA content of 25% and RCA of 15% exhibited optimum UCS and E values.

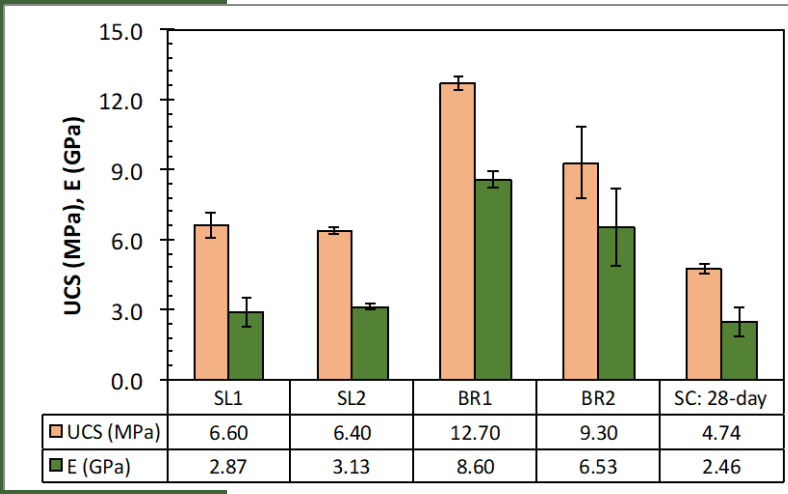

Figure 2. UCS and E of Soil-RCA geopolymer (72-h curing at 60°C) and soil-cement (SC-28-day at 25°C).

Based on the experimental results and sensitivity analysis of the mixture variables four mixtures were selected for further testing and comparison with soil-cement (SC) mixtures. It is evident from the results (shown in Figure 2) that the ultimate UCS and E of selected mixtures of BR flyash have higher values as compared to both soil-cement and SL flyash based geopolymer mixtures. The BR1 mixture exhibits the highest values and has twice as much UCS and 4 times the E values as soil-cement mixtures. For durability test all specimens were cured for 7 days at 25oC. It was found that the selected geopolymer mixtures and soil-cement mixtures passed the durability criteria of change in volume <2% and a change in mass of <10%. Even though both types of mixtures passed the durability criteria the geopolymer mixtures exhibited lower volume change and mass loss than the soil-cement mixtures.

Impacts

It is anticipated that the study will provide a cost-effective approach to enhance the durability and sustainability of pavement soil-base/subbase by utilizing recycled aggregates and alternate cementing materials such as Geopolymer binders. The results of experimentation will develop the basic understanding of soil stabilization and strength gain using the Geopolymer binders. The Louisiana DOTD and potentially other state DOTs can implement the newly developed Soil-RAG-Geopolymer mixtures for pavement base and subbase layers.

Tran-SET

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