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Flexible base course material stabilization using polymer-based stabilizing agents

J. T. D. Davis and G. Saygili

Department of Civil Engineering, The University of Texas at Tyler, Tyler, Texas

Abstract

The purpose of the base and subgrade layers of a pavement system is to resist shear and avoid excessive deflections. To increase shear strength, traditional stabilizers (commonly cement and lime) are added to most soils based on the soil's plasticity index. Non-traditional polymer-based products have become popular due to cost efficiency, ease of application, and fast curing times. They prevent base failure, dust pollution and soil erosion, increase soil shear strength, and reduce permeability. Research shows shrinkage cracks in the stabilized layer often occur with cement treated soils. Non-traditional polymer-based stabilizers show promise to provide economic, performance, and constructability benefits over traditional stabilizers, but a comprehensive database of behavior over a range of local conditions is unavailable. Compaction and unconfined compression tests on treated (cement and polymer-based product) iron ore base course materials were carried out to evaluate the performance of treated soils using a range of controlled parameters including 7 and 14 days of curing times. A control test with no additives was also performed for reference. Average unconfined compression strengths were around 4.5 and 2.5 times greater than the unconfined compression strength of untreated iron ore for polymer and cement stabilized samples, respectively.

Introduction

The primary purpose of the base and subgrade layers of a pavement system is to resist permanent deformations, to resist shear and to avoid excessive deflections. Base materials directly support pavement layers and tend to have higher strength and deformation characteristics. Base materials typically have the following minimum characteristics: (1) not more than 20% finer than a #40 sieve, (2) maximum (PL) plastic limit of 12%, and (3) maximum (LL) liquid limit of 40% (NCHRP 144, 2009).

As suggested in TxDOT 09/2005 and NCHRP 144, 2009, the main purposes for stabilization of base soils include increase in shear strength, reduction in moisture susceptibility, and utilization of local soils. Soil stabilization has been practiced for many years using traditional and non-traditional stabilizers.

Cement and lime are the two most common traditional stabilizers. Research findings over the years consistently have revealed that cement and lime treatment lead to significant increase in strength and durability of treated soils (TxDOT 09/2005 and NCHRP 144, 2009). For traditional stabilizers, the decision to choose lime, fly-ash or cement is primarily driven by the clay content of the soil as reflected in the plasticity index (PI). Soils with high PI are deemed good candidates for lime treatment, while more granular soils and those with lower PI typically are treated with cement.

Long term strength gain using lime is dependent on pozzolanic reactions. Final strength of the soil-lime mixture depends on many factors, with the amount of lime used, the in-situ and curing moisture content (which also impacts achievable density), and level of compaction achieved being large factors. Cement stabilization depends on hydration products immediately created by the calcium silicates and calcium aluminates present in the cement itself. Research findings reveal that cement treated soils show a brittle behavior which is often the reason for shrinkage cracks in the stabilized layer. Reflection cracks through the asphalt surfaces typically follow the same patterns as the cracks in a cement treated base (Wayne and David, 2004). Stabilization with fly-ash, while not as common in Texas, combines features of stabilizing with lime and cement. Class C fly-ash contains lime and glassy silicates and aluminates, and thus has some immediate cementing action and some long term pozzolanic action driven by excess lime.

Introduced as a non-traditional stabilizer for soil stabilization and erosion control, polymer-based products have become popular also due to cost efficiency, ease of application, and fast curing times. These polymer-based products prevent base failure, dust pollution and soil erosion, increase soil shear strength, and reduce permeability.

The objective of this paper is to discuss test on polymer-based soil stabilizers for use in subgrade layers to strengthen pavement by increasing shear strength, minimizing moisture levels, and reducing deformation points. The information presented includes (i) the engineering properties assessed through a pilot laboratory testing program and (ii) recommendations for a more comprehensive future study for stabilized base materials. (Future study recommendations are provided to identify gaps in the current knowledge base and critical variables, provide the objectives of the future work, and discuss the impact and significance of the expected outcomes.)

Materials

Iron ore is predominantly used as base course materials within the various TxDOT district counties. The grading upper and lower bound requirements for base course materials used in flexible pavements by various TxDOT district counties are presented in Figure 1 below. The red line displays the target gradation of the samples used for the compaction and unconfined compression tests. Gradation Identified from TxDOT test procedure (Tex-113-E, 3.10 and 6.2). The percent passing 40-mesh (i.e. soil binder) was around 33%.

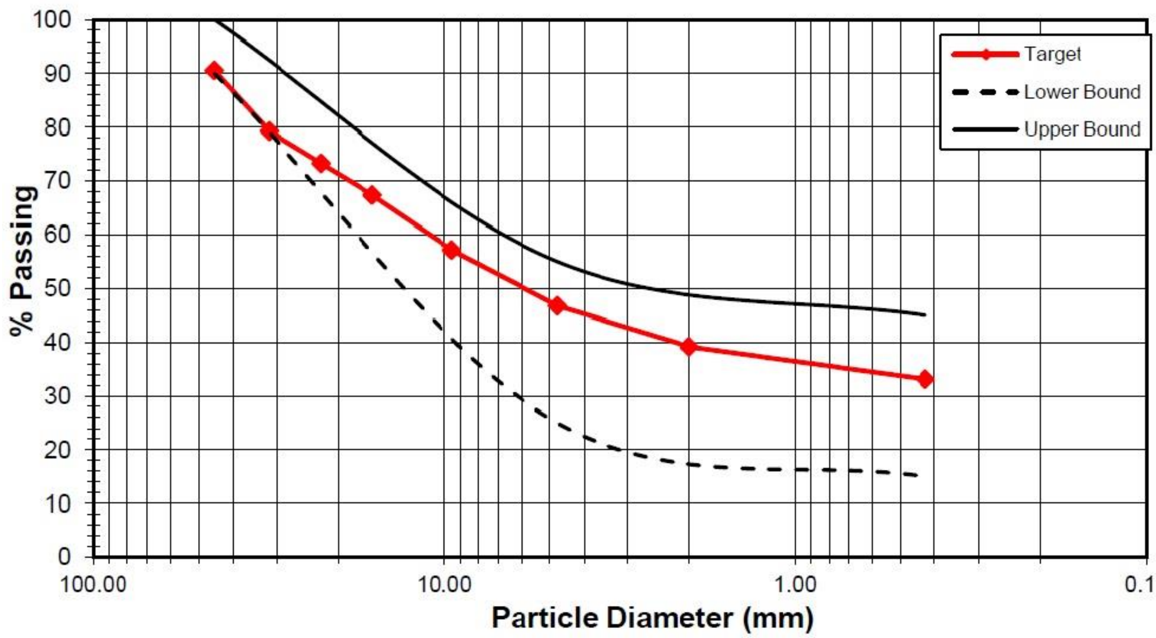

Figure 1: 247 Flexible base gradation requirements (Ref: TxDOT test procedures (Tex 100-E series),(Tex-113-E, 3.10, 6.2))

Test procedures

Compaction and unconfined compression tests were performed on treated (i.e. cement and polymer-based product) iron ore base course materials used in flexible pavements by various TxDOT district counties.

Soil samples were compacted in a standard mold having a capacity of 1/13.33 ft^3 and having an internal diameter of 6 inches with a height of 4.584 inches. Samples in the mold were compacted at optimum moisture content of 9.6% in three layers with 56 blows per layer from a 5.5 pound hammer dropped from a height of 12 inches. The compacted samples were cut to the specific height and extruded from the mold as seen in figure 2 below. Each sample with the cement mixture was placed in moist (humid) tubs to assure proper curing of each sample. Unconfined compression tests were carried out using Tinius Olsen 400 kip Super “L” universal tension-compression testing machine on compacted samples using a loading rate of 2.0% strain per minute. The polymer-based samples were left out to dry at ambient room temperature. After the 7 and 14 day cure times were met, the testing processes were completed.

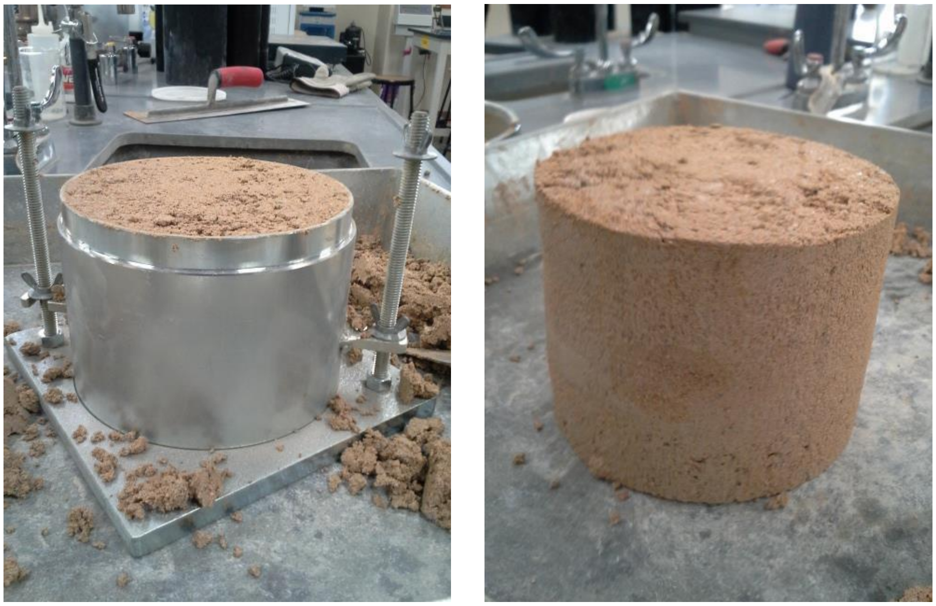

Figure 2: Prepared Flexible Base Samples

Pilot study results

Figure 3 displays the stress-strain curves obtained from unconfined compression tests using cement and polymer treated iron ore samples after 7 and 14 days of curing times. A control test with no additives was also performed for reference. The following observations are made:

Unconfined compressive strength

- The unconfined compression strength increases with both cement and polymer treatment
- The unconfined compression strength with 3% polymer is on average 4.5 times the unconfined compression strength of untreated iron ore
- The unconfined compression strength with 3% cement is on average 2.5 times the unconfined compression strength of untreated iron ore

Strain at peak stress

- The strain at peak stress of the control test is around 7.6%
- The average strain at peak stress of the polymer treated iron ore samples is around 7.2%
- The average strain at peak stress of the cement treated iron ore samples is around 3.4%

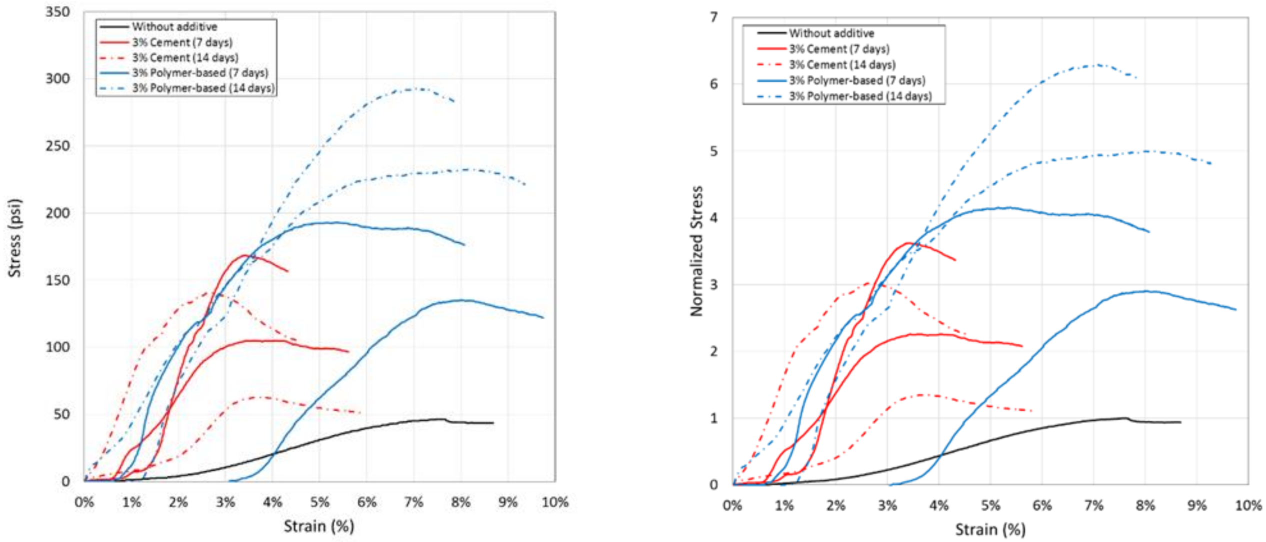

Figure 3 (a) Stress-strain and (b) Normalized Stress – Strain curves for iron ore flexible base materials

Future Study Recommendations

Gaps in the Knowledge Base

The following knowledge gaps are identified:

(1) Cement treatment of base course materials can show a brittle behavior which is often the reason for shrinkage cracks in the stabilized layer. Reflection cracks through the asphalt surfaces typically follow the same patterns as the cracks in a cement treated base (Wayne and David, 2004). This issue has not been adequately studied.

(2) Non-traditional polymer based stabilizers show promise to provide economic, performance and constructability benefits over traditional stabilizers, but a comprehensive database of behavior over a range of local conditions is not available.

Critical Variables

Laboratory investigations help to evaluate the performance of treated soils using a range of controlled parameters. The following critical variables are selected for a comprehensive laboratory testing program.

- Type of stabilizing agent (cement, lime, and polymer-based products)
- Effective stabilizing agent treatment levels (1%, 3%, and 5%)
- Levels of moisture conditioning (dry of optimum, optimum, and wet of optimum)
- Triaxial test axial load strain rates (standard and fast rates)

Future Study Objectives

Our aim is to help various TxDOT district counties reduce initial costs and to reduce frequency and intensity of routine maintenance for stabilized base materials by providing recommendations and suggestions for the following questions:

1. What are the expected shear strength values for various combinations of types of flexible base soil, stabilizing agent, and stabilizing agent treatment levels?
2. How does the curing time and strain-rate affect the strength properties of stabilized soils?
3. What is the moisture susceptibility of stabilized soils?

Independent comparative laboratory tests using traditional and non-traditional stabilizers will aid various TxDOT district counties to revise the current state of practices within the various offices.

Impact and significance

The results of this future study will impact various TxDOT district counties by enabling accelerated road construction techniques merit of this project lies in adoption of new stabilizers (polymer-based) and a strong collaborative relationship between the partnering institutions.

References

NCHRP 144 (2009), Recommended Practice for Stabilization of Subgrade Soils and Base Materials
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Terra Pave International (2014), Top-Seal White™, Liquid Base Stabilizer & Sealant
http://terrapaveinternational.com/products/top-seal-white/
TxDOT test procedures (Tex 100-E series)
Wayne S Adaska and David R Luhr. Control of Reflective Cracking in Cement Stabilized Pavements[C] , 5th International RIL EM Conference , Limoges , France , May 2004
using polymer-based products with ease of application and fast curing times. These techniques have the potential to reduce construction costs and represent a cost-effective way to better meet TxDOT’s strategic goals. The intellectual