

Validation and Refinement of Chemical Stabilization Procedures for Pavement Subgrade Soils in Oklahoma

ANNUAL REPORT FOR FY 2009
ODOT SPR ITEM NUMBER 2207

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Problem Statement: *To optimize and validate Oklahoma Department of Transportation Materials Division's recommended Standard OHD L-50 entitled, "Soil Stabilization Mix Design Procedure."*

Due to the prevalence of fine grained soils in Oklahoma it is common practice to use chemical stabilization in the construction of highway subgrades. Additionally, chemical stabilization is sometimes used in the construction of sub-base and base course layers using marginal quality aggregate materials. The traditional method of mix design for stabilized subgrade, according to ASTM D4609 for example, can be time consuming and create delays during design and construction. A test can take a week or more including sample collection, preparation, curing time and testing. If subgrade conditions are well known prior to construction, a mix design may be feasible; however, often times subgrade conditions are not well known during the design phase and differ from those encountered during construction. Thus, if an entirely new mix design is required significant delays in construction may occur.

In an effort to streamline the mix design process, the Oklahoma Department of Transportation Materials Division developed the OHD L-50 Standard entitled "Soil Stabilization Mix Design Procedure." At the heart of this standard is a table titled "Soil Stabilization Table", which provides recommended additive amounts for soils in the Soil Group Classifications found in AASHTO Standard M145. Additive amounts are given for Portland Cement (PC), Fly Ash (FA), Cement Kiln Dust (CKD), and Lime (hydrated and quick lime). OHD L-50 recommends a traditional mix design approach to address particular project concerns or non-approved chemical sources but allows projects having no unusual soil conditions to use the soil stabilization table. While the development of this table is based on a significant amount of research and experience in Oklahoma, it is possible that recommended additive amounts may not be appropriate for all soil and additive combinations within a particular soil group classification. In other words, the use of the recommended additive content may not achieve the desired effect that would normally be targeted in a full mix design process. The desired effect may be quantified, for example, in terms of the unconfined compression strength of the soil-additive combination after a standard amount of curing.

Objectives: 1) Refine and optimize the recommendations in OHD L-50 by examining potentially useful and quick methods for selecting additive contents, 2) Determine a correlation between stabilized soil strength gain and stiffness, 3) Understand the similarities and/or differences between predicted laboratory stabilized soil strength gain and stiffness and actual field conditions after construction and make necessary recommendations.

Proposed Activities for FY10:

The tasks necessary to complete the stated objectives include

- A) Select roadway projects in alignment characterization or grading and drainage stages which represent different sub-grade soil types, chemical additive types, and climatic conditions across Oklahoma,
- B) Collect representative soil samples from project locations for classification, quality control, and engineering property testing.
- C) Collect representative chemically treated soil samples from construction project sites for engineering property testing.
- D) Following compaction and acceptance of the chemically treated subgrade, conduct a time sequence (1, 3, 7, 14, 28 days) field evaluation of strength and stiffness using field test equipment, including the Dynamic Cone Penetration and PANDA Penetration Tests.
- E) Establish time rate of development and maximum level of strength gain relationships and compare to previous structural number correlations, then adjust design equation input parameters accordingly.

We will also continue the original project tasks (see next section for complete list) as follows:

C4. Quantify change in plasticity of stabilized soil using Atterberg Limit Tests.

E1. Use the linear shrinkage, SSA, pH and conductivity tests to determine protocols that would relate additive content to strength gain and take additive and soil variability (because tests are a function of mineralogy) into account.

Compilation of Completed and Work in Progress for FY09

The specific tasks addressed in FY09 are shown in italics:

A. Identify and investigate the variations in soil characteristics of Oklahoma Soils within each AASHTO Soil Group Classification (AASHTO M145).

***A1.** Examine the variability of surficial geologic materials, particularly along transportation corridors, using available published information including, but not limited to, soil surveys, geologic maps, and available records of subsurface exploration.*

***A2.** Interview personnel from ODOT headquarters and residencies across the state to identify typical as well as unusual soil behavior and to identify soil stabilization case histories of interest.*

***A3.** Collect three to five samples representing different soils within the same AASHTO M145 classification groups to represent the variations found in Oklahoma Soils.*

B. Determine the variability of chemical additives used for soil stabilization in Oklahoma.

B1. Determine the number and location of all approved additive sources used in construction of Oklahoma highways.

B2. Obtain existing chemical data and measure additional properties of these additives (as needed).

B3. Select and obtain one to three sources for each additive type.

C. Evaluate OHD L-50 “Soil Stabilization Mix Design Procedure” for the test soils and test additives identified in Objectives A and B.

C1. Determine testing schedule to optimize resources and time while considering the extent of soil and additive variability across Oklahoma.

C2. Determine basic physical and engineering index properties with standard laboratory tests.

C3. *Determine moisture-density curves of raw and treated soil via the calibrated Harvard Miniature Procedure.*

C4. *Quantify change in plasticity of stabilized soil using Atterberg Limit Tests.*

C5. *Determine unconfined compressive strength of raw and treated soils to assess degree of stabilization achieved using the recommended ODOT additive quantities.*

C6. Determine if the recommended additive contents meet the strength limits defined in ASTM D4609 and OHD L-50. Choose soils, including those that do not meet expectations, to perform further analyses as outlined in Objective E.

D. Thoroughly characterize the test soils identified in Objective A to determine mineralogical, physical, chemical, and engineering index properties and use the results of these tests to analyze the results observed in Objective C.

D1. Perform laboratory tests focused on physico-chemical understanding of soils including Specific Surface Area (SSA), powder X-Ray Diffraction (XRD), carbonate content, organic content, pH, electrical conductivity, iron content and Ion Chromatography (IC).

E. Refine and optimize the recommendations in OHD L-50 by examining potentially useful and quick methods for selecting additive contents.

E1. *Use the linear shrinkage, SSA, pH and conductivity tests to determine protocols that would relate additive content to strength gain and take additive and soil variability (because tests are a function of mineralogy) into account.*

September 2009

Overview of Work Done

The tasks completed include:

- Task C3: moisture-density curves with all additives for a A-7-6 soil to understand density-water content behavior
- -Task C3: moisture-density curves with all additives for a A-6 soil to understand density-water content behavior
- Task A3: Find additional A-4 soils to add to the database
- Task C5: Performing repeatability HM tests on Hollywood (A-7-6) soil to ensure accurate results
- Task C5: Performing HM tests on additional A-6 and A-7-6 soils to add to database
- Task C5: Determine unconfined compressive strength of raw and treated soils

Work in Progress

The following tasks are a work in progress:

- Task E1: maintaining growing database of all soils and properties and ensuring valid results
- Task E1: Performing linear shrinkage and shrinkage limit tests on stabilized soils to improve understanding of soil behavior
- Task C4: Performing Atterberg limit tests on 0-day and 14-day cured samples
- Task D1: Performing additional laboratory tests (SSA, CEC, pH, and conductivity) on stabilized samples

Field Work in Progress

- Task A: Two sites have been selected thus far. One in Geary, OK on US 281 which is has in-situ soils including A-4 and A-6 and is being treated with Class C Fly Ash from the Red Rock plant. The other site selected is on Penn Ave in Logan County north of Waterloo Rd. This site includes A-6 soils being stabilized with Class C Fly Ash from the Red Rock plant as well.
- Task B: Both of the previously mentioned sites have been sampled and approximately 300 kg of natural-untreated soil has been collected from each site for laboratory testing.
- Task C: Both of these two sites (US 281 and Penn Ave.) have been chemically treated and representative treated samples have been collected from both sites for the use of engineering property testing.
- Task D: Both of these sites have been treated and compacted and time interval testing has begun at both sites. Both the DCP and the PANDA have been used to determine strength and stiffness as well as the Falling Weight Deflector test has been used to

obtain a dynamic modulus. Testing has been done for the untreated soil and the treated/compacted soil at the US 281 location for 3 & 7 days and will be done for 14 days on October 8th, 2009. Testing at the Penn Ave. location has been done for 1 & 3 day testing and 6 day testing will be conducted on October 8th, 2009.

August 2009

Overview of Work Done

The tasks completed include:

- Task C3: moisture-density curves with all additives for a A-7-6 soil to understand density-water content behavior
- Task C3: moisture-density curves with all additives for a A-6 soil to understand density-water content behavior
- Task A3: Find additional A-4 soils to add to the database
- Task C5: Performing repeatability HM tests on Hollywood (A-7-6) soil to ensure accurate results
- Task C5: Performing HM tests on additional A-6 and A-7-6 soils to add to database

Work in Progress

The following tasks are a work in progress:

- Task E1: maintaining growing database of all soils and properties and ensuring valid results
- Task E1: Performing linear shrinkage and shrinkage limit tests on stabilized soils to improve understanding of soil behavior
- Task C5: Determine unconfined compressive strength of raw and treated soils

July 2009

Overview of Work Done

The tasks completed include:

- Task C3: moisture-density curves with all additives for a A-7-6 soil to understand density-water content behavior
- Task C3: moisture-density curves with all additives for a A-6 soil to understand density-water content behavior
- Task A3: Find additional A-4 soils to add to the database

Work in Progress

The following tasks are a work in progress:

- Task E1:maintaining growing database of all soils and properties and ensuring valid results
- Task E1:Performing linear shrinkage and shrinkage limit tests on stabilized soils to improve understanding of soil behavior
- Task C5:Performing repeatability HM tests on Hollywood (A-7-6) soil to ensure accurate results
- Task C5: Performing HM tests on additional A-6 and A-7-6 soils to add to database
- Task C5: Determine unconfined compressive strength of raw and treated soils

June 2009

Overview of Work Done

The tasks completed include:

- Task C3: moisture-density curves with all additives for a A-7-6 soil to understand density-water content behavior
- Task C3: moisture-density curves with all additives for a A-6 soil to understand density-water content behavior
- Task A3: Find additional A-4 soils to add to the database

Work in Progress

The following tasks are a work in progress:

- Task E1:maintaining growing database of all soils and properties and ensuring valid results
- Task E1:Performing linear shrinkage and shrinkage limit tests on stabilized soils to improve understanding of soil behavior
- Task C5:Performing repeatability HM tests on Hollywood (A-7-6) soil to ensure accurate results
- Task C5: Performing HM tests on additional A-6 and A-7-6 soils to add to database
- Task C5: Determine unconfined compressive strength of raw and treated soils

May 2009

Overview of Work Done

The tasks completed include:

- Task C3: moisture-density curves with all additives for a A-7-6 soil to understand density-water content behavior
- Task C3: moisture-density curves with all additives for a A-6 soil to understand density-water content behavior
- Task A3: Find additional A-4 soils to add to the database

Work in Progress

The following tasks are a work in progress:

- Task E1:maintaining growing database of all soils and properties and ensuring valid results
- Task E1:Performing linear shrinkage and shrinkage limit tests on stabilized soils to improve understanding of soil behavior
- Task C5:Performing repeatability HM tests on Hollywood (A-7-6) soil to ensure accurate results
- Task C5: Performing HM tests on additional A-6 and A-7-6 soils to add to database
- Task C5: Determine unconfined compressive strength of raw and treated soils

April 2009

Overview of Work Done

The tasks completed include:

- Task C3: moisture-density curves with all additives for a A-7-6 soil to understand density-water content behavior
- Task C3: moisture-density curves with all additives for a A-6 soil to understand density-water content behavior

Work in Progress

The following tasks are a work in progress:

- Task E1:maintaining growing database of all soils and properties and ensuring valid results
- Task E1:Performing linear shrinkage and shrinkage limit tests on stabilized soils to improve understanding of soil behavior
- Task C5:Performing repeatability HM tests on Hollywood (A-7-6) soil to ensure accurate results
- Task C5: Performing HM tests on additional A-6 and A-7-6 soils to add to database
- Task C5: Determine unconfined compressive strength of raw and treated soils
- Task A3: Looking for another A-4 soil (or two) to add to the database

March 2009

Overview of Work Done

The tasks completed include:

- Task C3: moisture-density curves with all additives for a A-7-6 soil to understand density-water content behavior
- Task C3: moisture-density curves with all additives for a A-6 soil to understand density-water content behavior

Work in Progress

The following tasks are a work in progress:

- Task E1:maintaining growing database of all soils and properties and ensuring valid results
- Task E1:Performing linear shrinkage and shrinkage limit tests on stabilized soils to improve understanding of soil behavior
- Task C5:Performing repeatability HM tests on Hollywood (A-7-6) soil to ensure accurate results
- Task C5: Performing HM tests on additional A-6 and A-7-6 soils to add to database
- -ask C5: Determine unconfined compressive strength of raw and treated soils
- Task A3: Looking for another A-4 soil (or two) to add to the database

February 2009

Overview of Work Done

The tasks completed include:

- Task C3: moisture-density curves with all additives for a A-7-6 soil to understand density-water content behavior
- -Task C3: moisture-density curves with all additives for a A-6 soil to understand density-water content behavior

Work in Progress

The following tasks are a work in progress:

- Task E1:maintaining growing database of all soils and properties and ensuring valid results
- Task E1:Performing linear shrinkage and shrinkage limit tests on stabilized soils to improve understanding of soil behavior
- Task C5:Performing repeatability HM tests on Hollywood (A-7-6) soil to ensure accurate results
- Task C5: Performing HM tests on additional A-6 and A-7-6 soils to add to database
- Task A3: Looking for another A-4 soil (or two) to add to the database

January 2009

Overview of Work Done

The tasks completed include:

- Task C3: moisture-density curves with all additives for a A-7-6 soil to understand density-water content behavior
- Task C3: moisture-density curves with all additives for a A-6 soil to understand density-water content behavior

Work in Progress

The following tasks are a work in progress:

- Task E1:maintaining growing database of all soils and properties and ensuring valid results
- Task E1:Performing linear shrinkage and shrinkage limit tests on stabilized soils to improve understanding of soil behavior
- Task C5:Performing repeatability HM tests on Hollywood (A-7-6) soil to ensure accurate results
- Task C5: Performing HM tests on additional A-6 and A-7-6 soils to add to database
- Task A3: Looking for another A-4 soil (or two) to add to the database

December 2008

Overview of Work Done

The tasks completed include:

Work in Progress

The following tasks are a work in progress:

- Task E1: Performing linear shrinkage and shrinkage limit tests on stabilized soils to improve understanding of soil behavior
- Task C3, C5: Performing repeatability HM tests on Hollywood (A-7-6) soil to ensure accurate results, as well as performing complete -moisture-density curves with all additives to understand density-water content behavior
- Task C5: Performing HM tests on additional A-6 and A-7-6 soils to add to database

November 2008

Work in Progress

The following tasks are a work in progress:

- Task E1: Performing linear shrinkage and shrinkage limit tests on stabilized soils to improve understanding of soil behavior
- Task C3, C5: Performing repeatability HM tests on Hollywood (A-7-6) soil to ensure accurate results, as well as performing complete -moisture-density curves with all additives to understand density-water content behavior
- Task C5: Performing HM tests on additional A-6 and A-7-6 soils to add to database

October 2008

Overview of Work Done

The tasks completed include:

- Task C4: Performed Atterberg Limits (14-day cured) on selected stabilized soils
- Task E1: Performed linear shrinkage on A-6 stabilized soil

Work in Progress

The following tasks are a work in progress:

- Task E1: Performing linear shrinkage and shrinkage limit tests on stabilized soils to improve understanding of soil behavior
- Task C3, C5: Performing repeatability HM tests on Hollywood (A-7-6) soil to ensure accurate results, as well as performing complete -moisture-density curves with all additives to understand density-water content behavior
- Task C5: Performing HM tests on additional A-6 and A-7-6 soils to add to database