LOUISIANA TRANSPORTATION RESEARCH CENTER
LTRC

TECHSUMMARY December 2020

State Project No. 30000661 / LTRC Project No. 11-1GT

In-Situ Evaluation of Design Parameters and Procedures for Cementitiously Treated Weak Subgrades using Cyclic Plate Load Tests

INTRODUCTION

Due to the soft nature of subsurface soils in Louisiana, roads are often constructed over very weak subgrade soils that do not have sufficient strength to support the construction/traffic loads, which pose a significant challenge for construction of highway projects. To solve this challenge, cementitious additives such as cement, lime, fly ash, cement kiln dust, and slag—alone or in combination—can be used to treat/stabilize these soils to improve their engineering properties (such as strength and stiffness), thus providing the needed support for pavement construction. Cementitious material can be used to treat soils to either provide a working platform for the construction of pavement shortly after mixing or enhance the strength and stiffness of soils in the long-term. The former is referred to as soil modification/treatment, while the latter is referred to as soil stabilization.

The common practice in Louisiana is to treat/stabilize in-situ weak subgrade soils or hauled soils with cement, lime, or a combination thereof, depending on the soil's plasticity index (PI). While the DOTD engineers provide recommendations on the selection of stabilizer type and content for treating hauled soils (controlled layer), the selection of stabilizer type and content for treating in-situ weak subgrade layer is based on achieving a specific compressive strength (50 psi for working platform and 100 psi for subbase application).

Many studies have shown that well-engineered and constructed cementitiously treated/stabilized subgrade soils can provide strong, stiff, and durable support to pavement structures. However, no credit is given to the treated/stabilized subgrade soils in the pavement design process. To give a reliable credit and include the structural contribution of the treated/stabilized subgrade soils, requires evaluating the performance of treated/stabilized soil layer in terms of resilient modulus (M_r) and permanent deformations. The composite resilient modulus ($M_{r\text{-}comp}$) representing the treated/stabilized subgrade soil and the underneath untreated soil need to be evaluated based on layers' thicknesses within the influence depth, as input for pavement design.

This study aimed at evaluating M_r for treated/stabilized subgrade soils of different plasticity, different moisture contents, and different additive type/dose. Guidance is also give on how to incorporate $M_{r\text{-}comp}$ in the pavement design process.

OBJECTIVE

- Evaluate the current subgrade treatment/stabilization schemes as provided in the *DOTD Standard Specifications for Roads and Bridges*.
- Examine the appropriate treatment/stabilization schemes for very weak subgrade soils at high water content condition with unconfined compressive strength < 25 psi (Phase II).
- Evaluate the performance-related properties (e.g., the M_r of treated subgrade layers and permanent deformation) for characterizing the cementitiously treated/stabilized subgrade layer for use in the design and analysis of pavements.
- Provide DOTD engineers with guidance on how to consider the cementitiously treated/stabilized very weak subgrade layer to create a working platform and/or stabilize subgrade in flexible pavement design, such as defining $M_{r\text{-}comp}$.

SCOPE

This research study consisted of two phases. Phase I evaluated the current subgrade treatment/stabilization schemes for hauled soil as provided in DOTD specifications; Phase II examined the appropriate treatment schemes for very weak in-situ subgrade soils at high water content. In Phase I, three soil types with different plasticity indices (PI) were considered. Stabilizer (cement and/or lime) was selected based on soil type. Repeated load triaxial tests (RLT) tests were performed to evaluate the M_r and permanent deformation (PD) characteristics of the stabilized specimens.

LTRC Report 627

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FUNDING:
SPR: TT-Fed/TT-Reg - 5

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Phase II included the selection of suitable stabilizer for wide range of soil types with different PIs and recommendation of the best stabilizer type and dose for use to a particular soil based on strength and PI. Four soil types with different plasticity were considered. The second part of Phase II included conducting RLT tests on the treated/stabilized weak soil specimens of different additive contents and moisture contents that achieve the minimum strength recommended by DOTD for use as working platform as well as subbase layer. The M_r and permanent deformation characteristics of the treated/stabilized specimens were evaluated.

METHODOLOGY

In this study, both laboratory and field testing programs were performed to evaluate the performance of cementitious treated/stabilized subgrade soils in terms of M_r and PD for use as a working platform and subbase applications. The laboratory testing included Atterberg limits, standard Proctor tests, unconfined compression strength (UCS) tests, tube suction tests, linear shrinkage tests, and RLT tests to evaluate M_r and PD characteristics of treated/stabilized specimens. The field testing program involved constructing and performing cyclic plate load tests (CPLT) on 10 test sections at LTRC's Accelerated Load facility (ALF) site.

For Phase I, only laboratory tests were performed on three selected soil types with different PIs that were stabilized based on PI values according to DOTD specifications. Standard Proctor tests were first conducted to evaluate the maximum dry density and optimum moisture content for use in sample preparation. UCS tests were performed to evaluate the strength of the stabilized specimens. Tube suction tests and linear shrinkage tests were conducted to evaluate the moisture susceptibility and shrinkage strain of stabilized specimens. RLT tests were conducted to evaluate M_r of stabilized specimens. Regression analysis were conducted using SAS software to evaluate the k_1, k_2, k_3 parameters for the AASHTO MEPDG M_r model. Finally, single-stage and multi-stage PD tests were performed to evaluate the PD characteristics of the stabilized specimens.

Phase II included both laboratory and field testing programs. Four soil types with different PIs were considered. Phase II testing focused on examining the appropriate treatment/stabilization schemes for very weak subgrade soils at high water contents with UCS < 25 psi. Standard Proctor tests were first performed on raw soils to evaluate the optimum moisture content. UCS tests were then conducted on raw soils prepared at different moisture contents on the wet-side of optimum to select three moisture contents with UCS ≤ 25 psi. UCS tests were conducted again on soil treated/stabilized soil specimens to select the appropriate additive and dose for use as working platform and subbase layer. Tube suction tests and linear shrinkage tests were conducted to evaluate the moisture susceptibility and shrinkage strain of stabilized specimens. Finally, RLT tests and single- and multi-stage PD tests were performed to evaluate M_r and PD characteristics of the treated/stabilized specimens. Regression analysis were conducted to evaluate the regression parameters for the AASHTO MEPDG M_r model.

The field testing program involved constructing and conducting CPLT tests on 10 test sections at the ALF site. The CPLT were applied using an MTS actuator, which has a force of 22 kips and a dynamic stroke of 6 in. (Figure 1). The CPLT tests were performed to evaluate $M_{r\text{-}comp}$ and PD of treated/stabilized sections at ALF site. After conditioning, multi-stage loading was conducted by applying 10,000 cycles for each deviatoric stress (total = 50,000 cycles). The selected deviatoric stresses were 9, 27, 44, 62, and 80 psi. The measured M_r values of the different test sections were back-calculated based on the assumption that the ratio (E_1/E_2)DCP for two-layers system obtained from DCP data is the same as the ratio (E_1/E_2)CPLT obtained from CPLT test.

CONCLUSIONS

- The proper selection of additive type and content for very weak and wet subgrade soils can substantially improve their performance in terms of increasing M_r and decreasing PD.
- Results of tube suction tests on treated/stabilized soil specimens showed that the maximum dielectric value (DV) ranged between 10 and 16 for Phase I and Phase II at 100 psi UCS, which means marginal material based on TxDOT's criterial.
- Results of RLT tests for Phase I showed that the M_r of treated/stabilized soil specimens ranged from about 25 ksi for soil #3 to about 36 ksi for soil #1.
- Results of RLT tests for Phase II showed that M_r of treated very weak soil specimens at 50 psi UCS ranged from about 5.5 ksi for soil #1 at MC 2 to 11 ksi for soil #3 at MC 3. However, for the 100 psi UCS, M_r of stabilized very weak soil specimens ranged from about 9.5 ksi for soil #4 at MC 1 to 14.5 ksi for soils #1 and #3 at MC 3.
- Results of single-stage PD tests showed that the treated/stabilized soil specimens had significantly lower permanent deformations compared to raw soils.
- Results of multi-stage PD tests demonstrated significant improvement on the behavior of treated/stabilized soils, as compared to untreated soils, especially at high stress ratios.
- The back-calculated M_r for the treated/stabilized test sections at ALF are in good agreement with the laboratory measured M_r for Phase II.

RECOMMENDATIONS

- It is recommended to start giving credit to the treated/stabilized subgrade soil through evaluating $M_{r\text{-}comp}$ of treated/stabilized soil layer and the underneath untreated subgrade soil.
- It is recommended to use the final selected additive combinations (lime, fly ash, and cement) and the corresponding contents by volume as presented in the report for treating/stabilizing the in-situ weak and wet subgrades soils based on PI values and in-situ moisture contents.
- It is recommended to evaluate the $M_{r\text{-}comp}$ and M_r of treated/stabilized subgrade sections' real pavement field projects constructed at different additive combinations for verifications.

Figure 1
Outdoor setup of cyclic plate load test