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Development of Models to Estimate the Subgrade and Subbase Layers' Resilient Modulus from In-situ Devices Test Results for Construction Control

Introduction

The current procedure concerning quality control/quality assurance (QC/QA) for the construction of pavement base courses and subgrade is mainly based on performing in-place moisture and in-place density tests. This procedure assumes that base courses and subgrade will perform satisfactorily in the field throughout their expected design life as long as an adequate field density is achieved. In general, the field density is measured relative to a maximum dry density under an optimum moisture content determined in laboratory Proctor tests. However, the design parameters of base course and subgrade materials in a pavement design are not based on density values or moisture contents but rather on the material's dynamic engineering strength and/or stiffness values, such as the resilient modulus.

With the advent of the new devices, such as Geogauge and light falling weight deflectometer (LFWD), that can be utilized in the QA/QC construction process, it is becoming easier to estimate stiffness of the pavement layers during the construction process. Although the devices can estimate reliable stiffness values of the pavement layers, they are not representative of design stiffness values used in the Mechanistic-Empirical Pavement Design Procedure Guide (MEPDG). This happens mainly when (1) the stresses applied by the in-situ devices are not representative values of traffic loads and (2) the in-situ devices are not designed for estimating the pavement layers stiffness (resilient modulus). These problems can be resolved by correlating the stiffness estimates from in-situ devices to the design resilient modulus determined in the laboratory. Thus, the correlations developed in this study will serve the purpose of a tool to estimate the resilient modulus of pavement layers during the construction process.

Objective

The primary objective of this research was to develop models that predict the resilient modulus of cohesive and granular soils from the test results of various in-situ test devices for possible application in QA/QC during construction of pavement structure. The secondary objective was to examine the effects of material type, moisture content, and dry unit weight on the resilient characteristics of investigated cohesive and granular materials.

Scope

The scope of this study includes conducting repeated load triaxial tests to determine the resilient modulus of materials similar to the ones used in the recently completed study "Assessment of In-situ Test Technology (AITT) for Construction Control of Base Courses and Embankment."

Laboratory repeated load triaxial resilient modulus tests were conducted on four cohesive soil types and three types of granular materials evaluated at various moisture contents and dry unit weight levels. The four types of cohesive soils included: A-4, A-6, A-7-5, and A-7-6 soils. The three granular materials were crushed limestone, Recycled Asphalt Pavements (RAP), and sand.

LTRC Report 406

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Cont'd on Back

Research Analysis

To achieve the objectives of this research study, the following major tasks were performed:

- Conduct a comprehensive literature survey of all published materials and ongoing research projects related to the use of in-situ test results for construction control.
- Conduct a laboratory testing program, which included performing repeated load triaxial resilient modulus tests and physical properties and compaction soils samples obtained during the field testing program of AITT study. For cohesive soils, cylindrical specimens of 71.1 mm (diameter) by 142.2 mm (height) were compacted in five layers using an impact compactor for the laboratory repeated load triaxial M_r tests. The laboratory resilient modulus test was conducted according to the AASHTO procedure T 294-94. While, for granular materials, cylindrical specimens of 152.4 mm (diameter) x 304.8 mm (height) were compacted for laboratory resilient modulus tests.
- Conduct a comprehensive statistical analysis using the Statistical Analysis System (SAS) program to develop models that predict the resilient modulus of cohesive and granular soils from the test results of various in-situ test devices for possible application in QA/QC during construction of pavement structure. Direct models that only consider the results from the different types of test devices were developed. In addition, multiple regression models were used to correlate M_r with the measurements obtained from each dynamic cone penetrometer (DCP) and continuous intrusion miniature cone penetration test (CIMCPT) and to determine the physical properties of tested soils.
- Prepare a final report that summarizes the results of this study.

Summary and Conclusions

This report presents a summary of the analysis that predicts the resilient modulus of cohesive and granular materials from the test results of DCP, LFWD, GeoGauge, and properties of tested material. Based on the results of this study the following conclusions can be drawn:

- Regression models were developed to predict the resilient modulus of cohesive soils and granular materials from the test results of DCP, GeoGauge, LFWD, and material physical properties.
- In general, good agreements were obtained between the resilient modulus values predicted from the proposed models and those measured in the repeated load triaxial resilient modulus test.
- The DCP-soil property model had the best prediction of resilient modulus of cohesive soils, followed by the DCP-direct model and GeoGauge-direct model.
- The GeoGauge-material property model was the best in predicting the resilient modulus of granular materials, followed by the DCP-material property model.
- As expected, the resilient modulus, DCP, GeoGauge, and LFWD test results were influenced by the moisture content, dry unit weight, and other physical properties of the tested soils.

Recommendations

The following initiatives are recommended in order to facilitate the implementation of this study:

1. Implement the DCP device in the resilient modulus-based QC/QA procedure during and after the construction of pavement layers and embankments.
2. Initiate a research project to implement and verify the M_r prediction models for cohesive soils. The research project should include different field projects covering various types of cohesive soils.
3. Validate the M_r prediction models for granular soils. The M_r prediction models that were developed in this study for granular soils were derived based on limited data points, hence it can be used for a relatively narrow M_r range. Therefore, future studies should be performed to incorporate more granular soils with wider M_r range, which will enhance the prediction of granular soils.