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Comparative Evaluation of Subgrade Resilient Modulus from Non-destructive, In-situ, and Laboratory Methods

Introduction

The Resilient Modulus (M_r) of pavement materials and subgrades is an important input parameter for the design of pavement structures. The Repeated Loading Triaxial (RLT) test typically determines M_r. However, the RLT test requires well trained personnel and expensive laboratory equipment in addition to being relatively time consuming. Therefore, highway agencies tried to seek different alternatives. Various empirical correlations have been used to predict M_r in the last three decades. Such correlations include parameters such as the soil support value (SSV), the R-value, and the California bearing ratio (CBR). In addition, different in-situ tests were used to develop models for the estimation of M_r of different pavement materials. These tests are characterized by the ease of operation and their ability to assess the structural integrity and estimate the elastic moduli of in-situ pavement layers. They have an additional advantage of being able to assess the pavement structure without destroying it.

Objective

The objective of this research was to develop models that predict the resilient modulus of subgrade soils from the test results of various in-situ test devices along with properties of tested soils. The in-situ test devices used were Dynamic Cone Penetrometer (DCP), Continuous Intrusion Miniature Cone Penetrometer (CIMCPT), Falling Weight Defelectometer (FWD), and Dynamic Deflection Determination (Dynaflect).

Scope

Field and laboratory testing programs were performed on soils of nine overlay rehabilitation pavement projects within Louisiana. A total of four soil types (classified as A-4, A-6, A-7-5, and A-7-6, according to the AASHTO soil classification) were considered at different moisture-dry unit weight levels. The field testing program consisted of conducting FWD, Dynaflect, CIMCPT, and DCP tests. Furthermore, Shelby tube soil samples were obtained from each tested section. Laboratory tests consisted of the determination of resilient modulus and physical properties of soil samples obtained from the field test sections.

Research Approach

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

- Conducted a comprehensive literature survey of all published materials and ongoing research projects related to the prediction of M_r from different in-situ testing devices.
- Conducted a field testing program, which included sections in nine overlay rehabilitation pavement projects (LA333, LA347, US171, LA991, LA22, LA28, LA344, LA182, and LA652) within

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Principal Investigator:

Kevin Gaspard, P.E.

LTRC Contact:

Zhongjie "Doc" Zhang, Ph.D., P.E.
Phone (225) 767-9162

Louisiana Transportation Research Center

Sponsored jointly by the Louisiana Department of Transportation and Development and Louisiana State University

4101 Gourrier Avenue
Baton Rouge, LA 70808-4443

Louisiana. For each test section, FWD, Dynaflect, CIMCPT, and DCP tests were conducted. In addition, Shelby tube soil samples were obtained. The FWD moduli were backcalculated using ELMOD 5.1.69, MODULUS 6, and EVERCALC 5.0 softwares.

- Conducted a laboratory testing program, which included performing repeated load triaxial resilient modulus tests and physical properties and compaction tests on samples obtained from the field test sections.
- Conducted a comprehensive statistical analysis using the Statistical Analysis System (SAS) program to develop models that predict the resilient modulus of subgrade soils from the results of various in-situ tests devices considered in this study. Two M_r Prediction models were developed. The first one, "Direct Model," considered only the results from the different types of test devices. The second model, "Soil-Property Model," incorporated measurements obtained from each DCP and CIMCPT test and the physical properties of the tested soils to predict M_r.
- Prepared final report that documented and summarized the study results.

Conclusions

In this study, models that predict the resilient modulus of subgrade soils from the test results of DCP, CIMCPT, FWD, Dynaflect, and soil properties of subgrade soils were developed. Based on the results of this study, the following conclusions can be drawn:

- The DCP soil-property model ranked the best for the prediction of resilient modulus of subgrade soils followed by the DCP direct model, CIMCPT soil-property model, CIMCPT direct model, Dynaflect model, and FWD models.
- A good agreement was obtained between the M_r predicted using DCPI and those measured using repeated load triaxial tests.
- The predicted M_r values obtained from the CIMCPT direct model, which included CIMCPT tip resistance and sleeve friction as independent variables, matched the measured M_r values using repeated load triaxial tests. This demonstrates the applicability of the CIMCPT test results in predicting the M_r of pavement subgrade cohesive soils.
- Soil properties influence the DCP and CIMCPT test results, and the two models were enhanced when moisture content and dry unit were incorporated.
- Among all backcalculated FWD moduli, those backcalculated using ELMOD 5.1.69 software had the best correlation with M_r measured in the laboratory using repeated loading triaxial tests.
- From a practical standpoint, the subgrade modulus determined from the DCP-soil property model, DCP-direct model, CIMCPT soil-property model, CIMCPT direct model, Dynaflect, or FWD utilizing ELMOD 5.1.69 backcalculation software may be used with the same confidence, considering the ranges of the coefficient of determination.

Recommendations

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

1) Implement the results of this study into the design manual for use by LADOTD engineers.

2) Establish an implementation and verification through field projects. Selected projects should incorporate various types of cohesive soils.

3) The models in this study were developed for cohesive soils and may not be capable of predicting M_r values of granular soils. Therefore, a new study should be conducted that incorporates granular soils in order to facilitate the development of generalized M_r prediction models for all soils encountered during construction of roadways in Louisiana.