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DEVELOPMENT OF A RELIABLE RESILIENT MODULUS TEST FOR SUBGRADE AND NONGRANULAR SUBBASE MATERIALS FOR USE IN ROUTINE PAVEMENT DESIGN

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PROBLEM STATEMENT

Highway engineers have relied on resilient modulus (M_R) measurements to predict how particular pavement materials will respond to repeated wheel loads. And the laboratory test most often used to measure M_R is that codified in 1986 by the American Association of State Highway and Transportation Officials (AASHTO). Designated AASHTO T-274-82, this test specifies that representative samples of roadbed soils be subjected to stress and moisture conditions that simulate actual field conditions. Yet, for a number of reasons, pavement engineers and designers have been sharply critical of the procedure. For example, they cite the procedure's requirement for laborious sample conditioning and testing, as well as its inability to reconcile the differences between the estimations of the moduli obtained from the field with those obtained under laboratory conditions. There have also been concerns regarding the test's reliability, repeatability, and efficiency. What this project undertook to provide, therefore, was an alternative test capable of accurately determining the resilient modulus of subgrade and nongranular subbase materials.

OBJECTIVES

The Center for Transportation Research (CTR) of The University of Texas at Austin, in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA), attempted in this project to develop a reliable resilient modulus test for subgrade and nongranular subbase materials for use in routine pavement design. Guided by this central objective, the CTR researchers identified the following specific tasks: (1) to develop a reliable and repeatable test procedure to measure resilient modulus; (2) to evaluate the factors (e.g., plasticity index, moisture conditions, density, and age-hardening) that affect the resilient modulus of soils; (3) to formulate more appropriate empirical models that can be used in both routine design and periodic evaluation of pavements; and (4) to compare the results from resilient modulus tests with those from other laboratory and in-situ tests to validate further the testing procedures and guidelines that are to be recommended.

CTR
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and the FHWA

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FINDINGS

After reviewing the available state-of-the-art equipment used for resilient modulus testing, the project team developed and assembled a dynamic loading system capable of evaluating the various resilient modulus tests. Customarily, the resilient moduli of cohesive and cohesionless materials have been determined in a repeated load triaxial compression test. The equipment used in this project was similar to that used in common triaxial testing, though some modification was required to accommodate the internally mounted (inside the triaxial chamber) load and deformation transducers. During the test, the researchers subjected the soil specimens to testing sequences that consisted of the application of different repeated axial deviator stresses under different confining pressures. Calibrated against synthetic specimens (urethane elastomers) of known stiffness characteristics, the testing equipment developed in this project was determined to be capable of providing accurate, repeatable, and reliable measurements. In terms of equipment configuration, the project team found that: (1) locating the two linear variable differential transformers (LVDT's) inside the triaxial chamber was the most effective method for obtaining accurate resilient axial deformations; (2) the entire resilient modulus test system—and not merely the individual transducers—requires calibration using, for example, synthetic samples of known properties; (3) grouting test specimens (with hydrostone paste) to the end caps of the triaxial chamber to prevent movement is very important; and (4) the entire design, installation, and use of a resilient modulus testing system requires careful effort and constant monitoring.

Next, the project team developed and tested a prototype resilient modulus testing procedure. For this testing, they collected 15 soil samples, representing a range of soil characteristics, from across Texas. Following their investigation, the study team concluded that sample conditioning is unnecessary and can thus be eliminated from the process. Moreover, they determined that the actual number of stress repetitions required for accurate estimates of moduli can be significantly reduced from the 200 repetitions specified in AASHTO T-274; specifically, they judged that 25 cycles were sufficient for obtaining accurate measurements of the modulus.

In addition, the new testing procedure proved effective in evaluating several other factors affecting the resilient modulus of soils. An analysis of these factors—plasticity index, the percent of fines, moisture content, dry density, and age of the soil sample at the time of testing—revealed the following:

(1) as the plasticity index increases, the M_R value slightly increases;
(2) as the moisture content increases (beyond the optimum moisture content), the M_R value decreases;
(3) as the dry density increases, the M_R value increases;
(4) the longer the sample ages, the more the M_R value increases;
(5) as the confining pressure increases, the M_R value increases; and
(6) as the deviator stress increases, the M_R value decreases.

In examining the factors that influence the overall moduli spectrum of compacted soils, the study team found that moisture content had the greatest effect, followed by the plasticity index, percentage of dry density with respect to the maximum density, age of the sample, confining stress, and deviator stress. The researchers also found that compacted soil age is an important factor in laboratory moduli measurements; they recommend testing the samples 2 days after preparation.

Finally, the authors developed moduli prediction models that can be used to obtain quick preliminary moduli estimates of pavement materials.

CONCLUSIONS

The authors propose that the resilient modulus testing method described in this report be used by pavement designers and engineers for evaluating subgrade and nongranular subbase materials. This method, in the view of the authors, represents a testing procedure that clearly outperforms AASHTO T-274 (and all other testing methods) with respect to efficiency, reliability, and speed.

In suggesting areas for further study, the authors recommend that more comparisons be made between laboratory and field moduli measurements to determine the most effective approach for selecting, sampling, and preparing more representative specimens for laboratory testing. Also, the AASHTO fatigue equations should be revised in accordance with the estimates obtained from the testing method reported here. Finally, the authors urge that further research be undertaken on granular base and subbase materials to develop a reliable testing method for those types of materials.

The information provided in this summary is reported in detail in Research Report 1177-4, "Development of a Reliable Resilient Modulus Test for Subgrade and Non-Granular Subbase Materials for Use in Routine Pavement Design," by Rafael F. Pezo, German Claros, and W. Ronald Hudson, January 1992.