TECHBRIEF

The Long-Term Pavement Performance (LTPP) program is a 20-year study of inservice pavements across North America. Its goal is to extend the life of highway pavements through various designs of new and rehabilitated pavement structures, using different materials and under different loads, environments, subgrade soil, and maintenance practices. LTPP was established under the Strategic Highway Research Program, and is now managed by the Federal Highway Administration.

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Improving Accuracy of Unbound Resilient Modulus Testing

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Background

A quality control/quality assurance (QC/QA) procedure has been developed for resilient modulus of soil and aggregate materials. This procedure can be used to achieve repeatable, reliable, high-quality resilient modulus data for soil and aggregate pavement materials. As evidenced from implementation in the Long-Term Pavement Performance (LTPP) program, it is a highly effective tool to reduce the historically large within- and between-laboratory variability associated with this test procedure.

Objectives

The P46 Laboratory Startup and Quality Control Procedure was developed to ensure the accuracy and reliability of the resilient modulus data produced while testing soil and aggregate materials using closed-loop servo-hydraulic systems. It was developed to provide performance benchmarks for resilient modulus testing equipment and laboratory technicians.

Products

The following key products have been developed:

- A detailed, step-by-step procedure to verify the ability of the testing equipment and laboratory personnel to perform resilient modulus testing of soil and aggregate materials.
- Verification standards and performance benchmarks for resilient modulus testing equipment and laboratory technicians.

Together, these products reduce the within- and between-laboratory variability of resilient modulus testing.

Benefits to Users

Any entity that is currently performing, intends to perform, or out-sources resilient modulus testing of soil and aggregate materials can benefit from the implementation of these procedures in the following ways:

Confidence The procedure can help produce reliable and accurate results from a resilient modulus testing program. It can also help in reducing the laboratory variability of the resilient modulus testing process for soil and aggregate materials that historically has been relatively large. Experience with Federal Highway Administration (FHWA) LTPP contract laboratories has demonstrated an accuracy of 3 to 8 percent within laboratory and 6 to 15 percent between laboratories. Use of this procedure should give the agency confidence in one of the key input parameters for pavement design decisions.

Effectiveness The procedure is tried and tested and has been successfully implemented at FHWA facilities in McLean, VA, and in two commercial laboratories under contract to FHWA. In addition, the procedure is undergoing evaluation and implementation in a number of state transportation agencies. Results to date have been extremely useful in quickly identifying existing and potential problems with the test equipment. Some of the problems discovered when using the procedure are:

- Over-ranged or fatigued load cells.
- Inadequate electronic filters and unmatched electronic filters.
- Software deficiencies.
- Inadequate signal conditioning and control.
- Oversize servo-valve and friction in servo-valve.
- Friction in triaxial cell seals.
- Bending of triaxial cell base plate.

Simplicity The bulk of the procedure requires standard equipment located in most testing laboratories, including a computer, calibrated proving rings, a linear variable deformation transducer (LVDT) calibrator, cables, and connectors. Some special equipment that may be present in the laboratory or can be purchased off-the-shelf are also required, such as an analog oscilloscope, function generator, and strain indicator.

Low Cost The cost of implementing these procedures is minimal when compared to: (1) the cost of obtaining and testing the samples on a large-scale basis and (2) the cost of constructing and rehabilitating pavement structures. The added value of knowing that the data generated by the resilient modulus testing program are of the highest quality and are not biased due to faulty equipment or operator error is a substantial benefit. The procedure can also be used by in-house staff to check older equipment that has not been used for a period of time, thus potentially saving thousands of dollars in equipment replacement costs.

Procedure Overview

The resilient modulus laboratory test protocol was developed to ascertain the elastic properties of the pavement base, subbase, and subgrade materials at stress states that are comparable to in situ pavement conditions. This value is a key input to current American Association of State Highway and Transportation Officials design procedures. It is also a basic material property that can be used in mechanistic analysis of multi-layered systems for predicting elastic deformations that ultimately correlate to pavement performance indicators such as roughness, cracking, rutting, faulting, etc.[2] Thus, the resilient modulus value derived from this testing process is a key parameter for pavement design and a key component of the LTPP data set.

This procedure is based on the premise that any engineering analysis requires reliable raw data. Prerequisites for reliable raw data are properly operating equipment and qualified technical staff to perform the procedure. The Laboratory Startup and Quality Control Procedure is designed to verify the operating accuracy of all the essential system components in a logical manner. Each part of the system is verified individually and then the entire system is checked to make sure all of the parts work together. The proficiency procedure is designed to evaluate the competency of the test technicians in performing this testing process.

System verification includes:

- Electronics System Verification Procedure. The signal conditioning channels, data acquisition processes, and transducers are checked for proper operation.
- Calibration Check and Overall System Performance Verification Procedure. Load and displacement measuring devices (i.e., load cells, LVDT's) are checked for linearity and proper

calibration. The ability of the software to control and acquire data is also assessed.

- Total System. After the process of verifying the individual system components is completed, the overall capability of the machine to conduct a specific experiment is assessed through specially designed static and dynamic experiments on materials with known properties.

Proficiency assessment is the phase of the process where the competence of the laboratory personnel to prepare samples and test both Type 1 (coarse-grained) and Type 2 (fine-grained) samples is evaluated. For both sample types, the entire test procedure is observed, beginning with breaking down the bulk material samples through the actual testing and recording of load and deformation data. Through the use of this procedure, all of the components necessary to obtain repeatable, accurate resilient modulus test results are verified.

Generalized Approach and Applicability

Although the original intention for developing the procedure was for the LTPP resilient modulus program, this efficient and inexpensive procedure can be implemented to verify most closed-loop, servo-hydraulic testing systems. The equipment required to conduct the procedure is readily available off-the-shelf and includes instruments such as an oscilloscope, function generator, and a computer, which are usually available in a testing laboratory.

The procedure is divided into three distinct components:

- Electronics System Performance Verification Procedure.
- Calibration Check and Overall System Performance Verification Procedure.
- Proficiency Procedure.

The *Electronics System Performance Verification Procedure* characterizes the frequency response of the signal conditioners and data acquisition system of the testing system. This procedure is generally used prior to the initiation of a resilient modulus testing program. As long as all of the electronic parts of the testing system remain the same, this procedure does not necessarily need to be repeated on a continuing basis (i.e., monthly). However, the procedure should be conducted at least every year to verify that the equipment meets the acceptance criteria or when any part of the electronics system is replaced or modified. Also, this procedure should be performed when other circumstances suggest that the electronics may be suspect. Generally, an electronics technician well-versed in data acquisition systems is needed to perform these experiments. The amount of time required to perform this procedure depends on the complexity of the testing system and the experience of the electronics technician. On average, this procedure will take approximately 8 to 10 h to complete (including data analysis).

The Calibration Check and Overall System Performance Verification Procedure is where individual elements of the testing equipment will be checked first, followed by the overall test setup. The resilient modulus testing procedure requires a system made up of many different pieces of equipment--load frames, load cells, hydraulic system, LVDT s, triaxial pressure chamber, computer, signal processor, etc. This procedure will verify that the testing system is producing the expected responses. By first checking the individual components of the testing system, it is expected that many problems that would be encountered during actual testing can be identified and eliminated prior to checking the overall system. This procedure is generally used prior to initiation of a resilient modulus testing program and subsequently on a continuing basis (i.e., monthly) to verify the system response. On average, the procedure requires approximately 8 h to complete.

The Proficiency Procedure evaluates the ability of the laboratory personnel to properly conduct resilient modulus testing. For both fine and coarse samples, the entire test procedure is observed by personnel who are very familiar with the procedures, beginning with breaking down the bulk material samples, through the actual testing and recording of load and deformation data. This procedure is generally used prior to initiation of a resilient modulus testing program and then on a continuing basis (i.e., quarterly) to verify the operator s ability to conduct resilient modulus testing. The procedure requires approximately 2 days to complete (including preparation, compaction, etc.).

The procedure was designed based on three criteria; effectiveness, simplicity, and low cost. It was formulated to be as general as possible so that it could be implemented by a wide variety of testing laboratories. Its growing implementation by laboratories nationwide is an indication of the procedure achieving its objectives to produce quality resilient modulus data and to reduce test variability as much as possible. Nonetheless, with the wide range of technology used in testing laboratories, each laboratory may have to adopt slightly different methods to perform the procedure, particularly the electronics verification procedure. The purpose of this procedure is not to verify the manufacturer's specifications nor to set new specifications for manufacturing equipment. This procedure is merely a powerful and inexpensive tool for the equipment operator to verify equipment accuracy before and during production testing. A certain level of expertise is required at each laboratory to ensure proper wiring for the Electronics System Performance Verification Procedure. This procedure should be implemented with caution and by qualified technicians or engineers.

References

1. Alavi, S.; T. Merport; T. Wilson; J. Groeger; and A. López, *LTPP Materials Characterization Program: Resilient Modulus of Unbound Materials (LTPP Protocol P46) Laboratory Startup and Quality Control Procedure*, Publication No. FHWA-RD-96-176, Federal Highway Administration, 1996.

2. *AASHTO Guide for Design of Pavement Structures*, American Association of Highway and Transportation Officials, Washington, DC, 1993.

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