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Assessment of Nondestructive Testing Technologies for Quality Control/Quality Assurance of Asphalt Mixtures - Tech Transfer Summary

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tech transfer summary

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RESEARCH PROJECT TITLE

Assessment of Non-Destructive Testing Technologies for Quality Control/Quality Assurance of Asphalt Mixtures

SPONSORS

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The Asphalt Materials and Pavements Program (AMPP) at InTrans specializes in improving asphalt materials and pavements through research and technology transfer and in developing students' technical skills in asphalt.

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Evaluation of the actual performance (quality) of pavements requires in situ nondestructive testing (NDT) techniques that can accurately measure the most critical, objective, and sensitive properties of pavement systems.

Background

The American Association of State Highway and Transportation Officials (AASHTO) Mechanistic-Empirical Pavement Design Guide (MEPDG) was developed to enable quantitative performance prediction for the design of new and rehabilitated pavement structures.

In addition to traffic and climate data, the mechanistic-empirical (M-E) design procedure requires measurement of fundamental pavement material properties rather than use of empirical relationships. Therefore, quality control and quality assurance (QC/QA) procedures based on measured fundamental properties are necessary to enable quantitative evaluations of pavement condition and performance.

Significant time and financial resources are currently spent on QC/QA testing of asphalt pavement construction projects. Substantial research efforts have focused on several non-destructive testing (NDT) technologies for flexible pavements, with the goals of improving the speed and accuracy of QC/QA methods and enabling the state of practice to evolve beyond destructive testing.

Some examples of these NDT technologies are nuclear gauges, electromagnetic gauges, permeability-based approaches, seismic testing techniques, and intelligent compaction. However, the destructive and relatively time-consuming coring process for laboratory measurement of density continues to be the most widely used QC/QA method in the US.

The process of coring slows construction progress, while placement of inadequate pavement before test results are obtained can cause project delays and financial penalties. In addition, the destructive coring process creates holes in the new pavement that are sometimes improperly repaired, leaving it more susceptible to premature failure.

Problem Statement

To obtain a more performance-based measure of pavement quality, significant progress has been made in several previous studies on in situ measurement of dynamic modulus of asphalt pavements by seismic testing methods. However, more robust and less delicate seismic testing systems still need to be developed for seismic testing methods to provide consistent, reliable and objective results.

In addition, a straightforward and practical QC/QA procedure is needed to convert the in situ dynamic modulus measurements to more quantitative measures of pavement quality. Both of these research needs were addressed in this study.

Project Objectives

The objectives of this project were to assess the performance of several in situ NDT technologies for QC/QA of asphalt mixtures and to perform a preliminary study of micro-electromechanical systems (MEMS)-based sensors for QC/QA and health monitoring of asphalt pavements.

Research Description and Methodology

Five representative paving projects in Iowa were selected for NDT:

1. Newly-constructed pavement sections at the Central Iowa/Boone County Expo site featuring low-volume roads with hot-mix and warm-mix asphalts (HMAs and WMAs), with various base and pavement treatments, construction techniques, and equipment
2. US 69, a medium-volume road with HMA resurfacing
3. US 169, a medium-volume road with HMA resurfacing
4. IA 93, a low-volume road with three different resurfacing methods: cold-in-place (CIP) recycling, thin overlay (OL), and full-depth reclamation (FDR)
5. US 6, a high-volume road with HMAs and WMAs containing steel slag

For each project, six or more test locations were randomly selected for measurement using three NDT methods:

1. Shear-wave velocity measurements using a custom-developed surface wave testing system (Figures 1 and 2)
2. Stiffness measurements using the Humboldt GeoGauge
3. Density measurements using the Troxler PaveTracker electromagnetic gauge

Figure 1. Surface wave testing on US 6

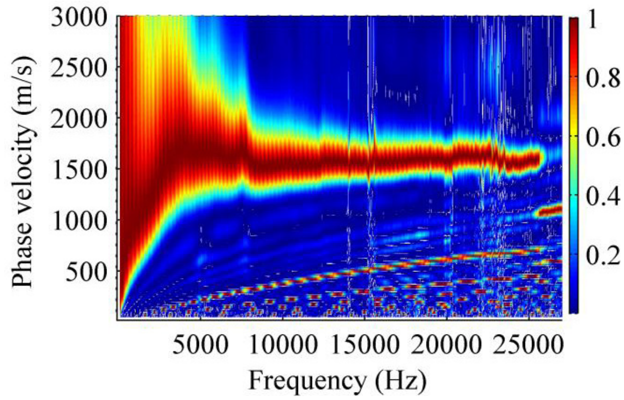

Figure 2. Dispersion data (phase-velocity versus frequency) from surface wave testing on US 6

All pavement testing locations were then cored for laboratory testing. Because asphalt stiffness and shear-wave velocity are very sensitive to temperature, the asphalt surface layer temperature was also measured in all field tests.

Hot tests were performed up to a few hours after paving; then, cold tests were performed after cooling the pavement surface with dry ice. Additional ambient-temperature tests were also performed on several projects one or more days after paving to examine the influence of temperature and asphalt curing on the NDT measurements. This can be important for properly interpreting the results of in situ tests, which will inevitably be performed over a range of seasonal ambient temperatures in practice.

Laboratory tests were performed on selected field cores, including density measurement by saturated surface dry (SSD) and CoreLok methods, and dynamic modulus tests using the indirect tension (IDT) method (Figure 3).

A master curve was constructed for each pavement section to correct the in situ moduli measured at different field temperatures to the moduli at a common reference temperature. A quality measurement procedure was then developed, in which the corrected in situ moduli are compared to their design values.

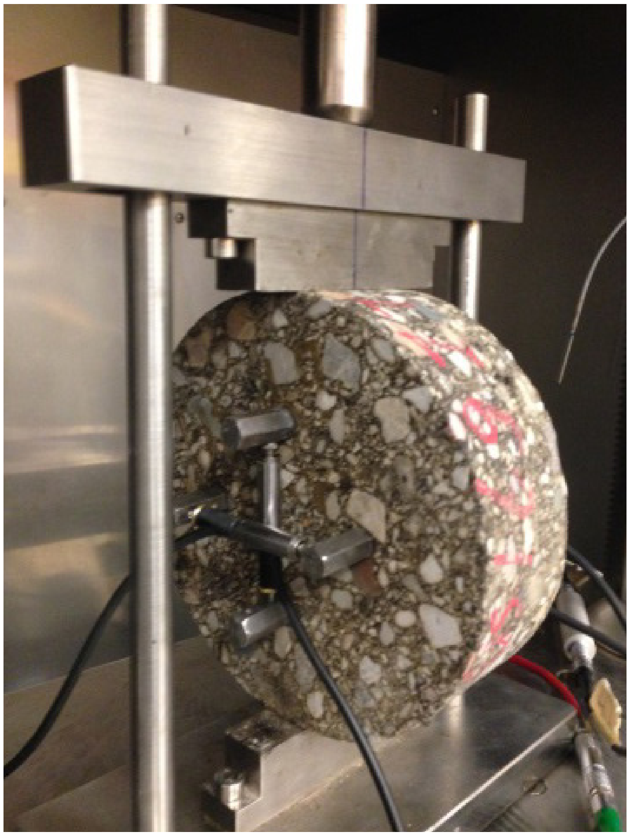

Figure 3. Laboratory dynamic modulus testing of field cores by indirect tension method

Key Findings and Recommendations

Conclusions from the results of this study can be summarized as follows:

- The in situ PaveTracker density has a low correlation with laboratory density, and is not sensitive to variations in temperature or pavement type. Therefore, QC/QA based solely on in situ density measurement by this device is not recommended.
- The GeoGauge stiffness measured on hot asphalt mixtures several hours after paving has a high correlation with in situ dynamic modulus and laboratory density, whereas the stiffness measured on cold and ambient-temperature asphalt mixtures has a very low correlation with the other measurements. Therefore, the GeoGauge stiffness measured on hot asphalt mixtures is recommended for QC.
- Among all methods examined, the shear-wave velocity from surface wave testing is the most sensitive to variations of temperature and pavement type. Therefore, shear-wave velocity is an objective property to measure asphalt pavement quality.
- The in situ density and shear-wave velocity measurements can be combined to calculate the in situ dynamic modulus, which is directly related to pavement performance. To account for temperature effects and provide a uniform quality comparison, the in situ modulus measured at a given field temperature should be corrected to the modulus at a common reference temperature.
- The laboratory moduli measured with the IDT method are in good agreement with those measured with the axial method (AASHTO T 342-11). The moduli of samples measured over a range of frequencies and temperatures was used to construct master curves, with one of the reference temperatures chosen to be the same as one of the field-test temperatures.
- To construct a master curve for the field temperature given laboratory modulus measurements at other temperatures, linear interpolation of logarithmic moduli from the measured master curves was found to yield the best agreement with the curve measured at the actual field temperature.
- The measured and interpolated master curves from laboratory tests on cores by the IDT method can be employed to correct the in situ moduli measured at different field temperatures to the moduli at a common reference temperature.
- A modulus-based QC/QA procedure was developed that is accurate, objective, and sufficiently sensitive to quantitatively measure the quality of asphalt mixtures (Figure 4).

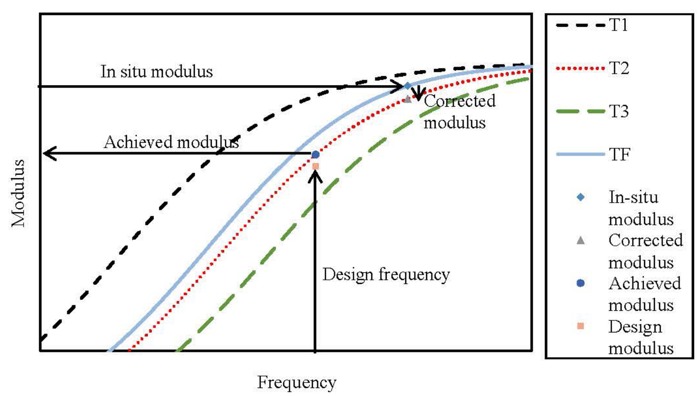

Figure 4. Quality assurance procedure based on modulus obtained by NDT measurements of shear-wave velocity and density (T1, T2, and T3 are temperatures for laboratory dynamic modulus tests and TF is the field test temperature)

- A preliminary study on MEMS-based sensors identified a battery-free, wireless, radio-frequency identification (RFID), passively-powered sensor technology that shows promise for further development of embedded strain gauges for QC/QA and health monitoring. Among three different configurations of the sensor tested, one configuration was found to survive the paving process and the sensor was successfully interrogated through 2 inches of asphalt pavement, giving temperature measurements immediately after paving as well as one week later.

Implementation Readiness and Benefits

Increased implementation of the NDT methods identified below for QC/QA of asphalt pavements can provide benefits by reducing costs and time required for destructive coring:

- In situ density measured with electromagnetic gauges can be combined with shear-wave velocity from surface wave tests, to calculate an in situ dynamic modulus, which is directly related to pavement performance.
- To account for temperature effects and provide a uniform quality comparison, the in situ modulus measured at a given field temperature should be corrected to the modulus at a common reference temperature.
- GeoGauge stiffness measured on hot asphalt mixtures is recommended as another alternative for QC.
- For health monitoring, baseline shear-wave velocity measurements from surface wave testing or GeoGauge stiffness measurements can be taken soon after construction or at some point in a pavement life. The baseline values can then be compared to periodic NDT measurements to monitor pavement performance and health.

A comprehensive master-curve database covering a variety of pavements with different mixes and traffic volumes is needed to correct the in situ modulus values for temperature, and to determine design modulus values. To generate such a comprehensive master curve database, laboratory modulus measurements of field cores from various asphalt pavement projects should be made.

The passively-, RFID-powered MEMS-based sensor technology should be studied further for application to embedded strain gauges for QC/QA and health monitoring.

The use of NDT tests performed periodically is also recommended for health monitoring of asphalt pavements.