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DEVELOPMENT OF ROUTINE RESILIENT MODULUS TESTING: NEW DEVICES AND PROCEDURES

PROBLEM STATEMENT

When designing and evaluating asphalt pavements, engineers must have an understanding of how the pavement materials will react to the stresses and strains of vehicle loads at varying temperatures. When a load is applied to asphalt concrete at a certain temperature, to what degree will the pavement "bounce back" to its original height? Pavement designers predict this spring-like behavior by obtaining the resilient modulus of the material — a single number that describes the stress-strain relationship. If a pavement has a high resilient modulus, then we can indirectly assume it will have better performance and less permanent deformation.

The 1986 AASHTO (American Association of State Highway Transportation Officials) Guide for Design of Pavement Structures incorporates resilient modulus testing of pavements into the design and evaluation procedure, and the *Asphalt Aggregate Mixture Analysis System* (AAMAS, NCHRP Report 338) uses resilient modulus to measure engineering properties (fatigue and thermal cracking, moisture damage, and rutting predictions) of mixtures and then judge the potential of these mixtures to function in pavement layers. The Texas Department of Transportation (TxDOT) has not routinely performed resilient modulus tests in the past. Additionally, the most common existing laboratory and nondestructive field tests (NDTs) for Resilient Modulus have shown limitations such as instrumentation problems, deviation of the actual procedure from the theory upon which it is based, and wave propagation anomalies.

OBJECTIVES

The Texas Transportation Institute (TTI) conducted study 1177, *Development of Routine Resilient Modulus (R_m) Testing for Asphalt Bound Materials*, in cooperation with TxDOT and the Federal Highway Administration (FHWA) to develop a reliable laboratory testing method for determining resilient modulus along with the 1986 AASHTO Guide and the NDT program, ultimately aiming to improve pavement design and evaluation in Texas. Researchers designed and fabricated two indirect tension devices (one generalized and one rapid diametral) and one axial loading device, while developing resilient modulus test procedures for their use. Machine drawings for the critical components are provided in TTI Research Report 1177-1F, as well as thorough background discussions of existing resilient modulus test methods, material behavior, and resilient modulus in relation to AAMAS.

As the testing devices were being developed, researchers conducted a test program to evaluate the equipment. In the initial test series, only the axial loading device, with non-contact radial measurement transducers, and the generalized indirect tension apparatus were used. Over 30 tests were conducted in this initial series. After development of the rapid diametral indirect tension device, over 650 additional tests were conducted to compare and refine all three devices and to document a test procedure for the department.

FINDINGS

Two different tests are commonly used to obtain the modulus of flexible pavements—a repeated load triaxial compression test or the diametral indirect tension test. Basically, an asphalt concrete specimen is carefully placed between a base and a loading block, which is forced down on the specimen by an actuator. Sensors mounted on the device (or the specimen) measure the resulting movement. Most axial testing devices have only been effective with relatively tall cylindrical specimens. Indirect tension devices have shown problems associated with mounting sensors and specimen alignment on the loading axis. There is also a need to maintain maximum speed and simplicity and to measure movement on both the vertical and horizontal axis.

New Devices

Researchers improved one device for axially loaded specimens and developed two devices for testing indirect tension of diametrally loaded specimens. An existing axial loading apparatus was modified by emphasizing the development of on-sample measurements. Because shorter in-service pavement cores almost never have parallel ends and should not be capped, load application almost always results in some specimen tilting or sliding. So in the new device, the sensors are glued directly to the surface of the specimen using small mounting fixtures.

Two indirect tension devices, a generalized and a rapid diametral, were developed and tested. The generalized indirect tension device is capable of measuring Poisson's ratio (another number used to describe the movement of the material), as well as resilient modulus. Past criticism of measuring Poisson's ratio in the diametral test has involved the development of a plastic zone in the vicinity where the loading strip contacts the specimen, which can cause inaccurate vertical deformation readings. In the new device, the loading strips are glued to the specimen in an alignment frame, which insures that the strips are located on the diameter and that the specimen will be loaded through the center. Hot glue works well for this application; however, the testing must be conducted at a sufficiently low temperature with the glue film thickness kept at a minimum. Four spring loaded sensors are positioned on each side of the specimen, and the loading strips allow the specimen to be easily turned for measurement of both vertical and horizontal displacements.

The accelerated diametral device is useful for conducting high-volume testing requirements. In order to equip the device with a firm mounting struc-

Time Estimates for R_m Testing Devices

Device	*Testing for ...*	*Preparation & Testing Time*
Generalized Indirect Tension Device	Resilient modulus R_m with ability to measure Poisson's Ratio.	9 – 10 minutes
Rapid Diametral Testing Device	Very rapid R_m testing for high volume requirements.	2 – 4 minutes
Axial Loading Apparatus	R_m through axial loading of short pavement cores.	20 – 40 minutes

Table 1. Minimum time requirements and uses of three testing devices.

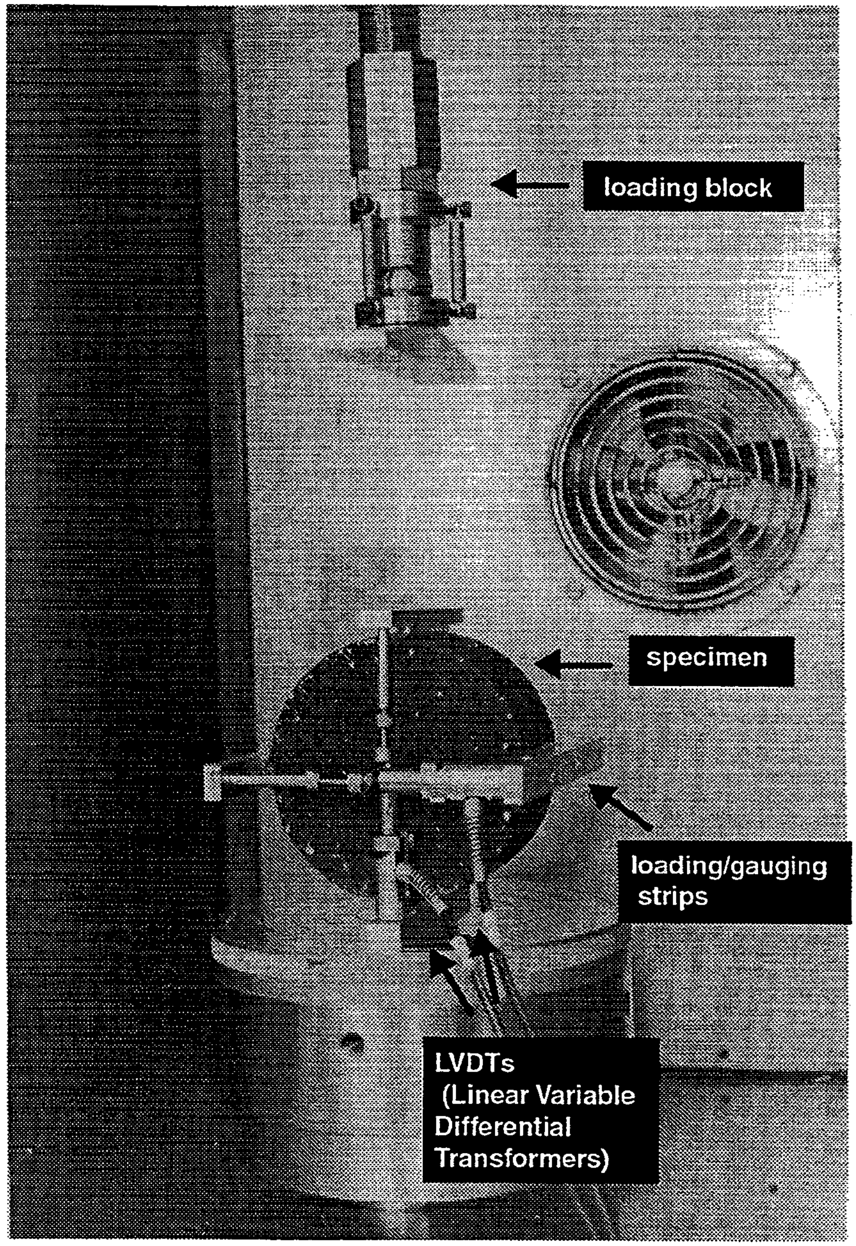
ture that would also move under loading *with* the specimen, researchers mounted a yoke system to the specimen with spring loaded, grooved, linear bearing shafts to hold it in place. The rapid testing device meets the objective of maximizing test speed quite well. However, it showed a key deficiency—the measured strains were apparently less than the actual specimen strain. Its development was initiated too late in the project for the deficiencies to be completely corrected.

Test Results

Chapter IV of Research Report 1177-1F details the experimental design, materials and methods used in the study's test program to evaluate and compare the new equipment and proposed test procedures for obtaining Resilient Modulus. Table 1 shows the minimum time requirements identified for each device.

The following technical points also resulted from these tests:

- The test procedure is capable of distinguishing among important mix variables.
- Results from axial testing at a continuous frequency of 10 Hz corresponds well to the diametral test results. This frequency corresponds to the frequency of the load pulse portion of the diametral wave form.
- The qualitative features of the expected temperature and frequency dependent response to loading were observed with the new equipment.
- No statistically significant difference was observed between loading with a pneumatic actuator and loading with a hydraulic actuator.



The Generalized Indirect Tension Testing Device uses an alignment frame to glue the loading strip to the specimen.

- When using commercially available sensors and signal conditioning equipment in resilient modulus testing, the equipment should be checked to verify that the individual unit has a small noise level and that relatively large noise signals do not appear at frequencies used in the test.
- The materials tested apparently dilated slightly, especially at the higher temperatures and load levels.
- Laboratory tests performed to corroborate NDT results should be conducted at the temperature (and as close to the frequency as possible) that was used in the field test.
- As few as 5 specimens of a given mix can produce a significantly desirable drop in the error rate. Up to 25 specimens

may be required to reach an optimum practical error rate. Fewer specimens may be tested if the resulting error rate is acceptable to the engineer. The number of specimens needed is also a function of the testing device, temperature and mix homogeneity.

CONCLUSIONS

This area of research is presently undergoing considerable change as the SHRP and AAMAS programs enter final stages and activity with creep testing and frequency sweeps increases. The developments in this study have been directed toward short term implementation and production, while aiming for long term flexibility to cope with new research findings. The testing devices were delivered to TxDOT in November 1991, and TTI currently uses the generalized indirect testing device to obtain resilient modulus. The devices should be used in conjunction with the test procedure given in Appendix B of Research Report 1177-1F. The procedure should be revised as necessary to keep pace with AAMAS methodology and emerging SHRP testing, design, and evaluation procedures.

The clamping apparatus on the accelerated indirect tension testing device should be evaluated for improvement. Decreasing the weight of the instrumentation yoke would be a small improvement. However, until deficiencies involving the apparent underestimation of strains can be corrected, Method A of Part II of the test procedure (Appendix B) should not be used. Further research could consider using the yoke system on the accelerated device for a *vertical*, as well as the horizontal, measurement application. In fact, there is an interesting possibility that the accelerated design developed in this study could be combined with a SHRP resilient modulus device which uses a similar sensor mounting arrangement on the inside diameter of the specimen. This could then result in an *accelerated* testing device that also measures vertical and horizontal movement.

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The information in this summary is reported in detail in TTI Research Report 1177-1F, "Resilient Modulus of Asphalt Concrete," November 1991; Revised April 1992, by D. Little, W. Crockford, and V. Gaddam. The contents of the summary do not necessarily reflect the official views of the FHWA or TxDOT.