Quality Management of Flexible Pavement Layers with Seismic Methods: Test Methods

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Introduction

The focus of Project 1735 has been on nondestructively measuring moduli with four inter-related seismic devices. Two of these are laboratory devices: the free-free resonant column device for testing base and subgrade and the ultrasonic device for testing HMA cores and molded specimens. The other two are field devices: the Portable Seismic Pavement Analyzer (PSPA) for testing HMA layers and a version of it that works on the base and prepared subgrade layers (affectionately called DSPA for Dirt Seismic Pavement Analyzer).

Procedures have been developed to measure the moduli of each pavement layer shortly after placement. These procedures allow rapid data collection and interpretation. Thus, any problem during construction process can be identified and adjusted. The proposed equipment and methodologies may strike a balance between the existing level of sophistication in the design methodology, laboratory testing and field testing. Performing the simplified laboratory and field tests along with more traditional tests may result in a database that can be used to smoothly unify the design procedures and construction quality management.

The major advantage of seismic methods is that similar results are anticipated from the field and laboratory tests as long as the material is tested under comparable conditions. This unique feature of seismic methods in material characterization is of particular significance, if one is interested in implementing performance-based specifications. Another advantage of the protocol is that seimic methods can characterize material properties with depth and dilineate between different materials or change in the material.

The overall protocol to be implemented is described in this document followed by step by step procedures on how to implement them in actual projects. We encourage the readers to review Research Report 1735-3 before reviewing the remainder of this report. Even though we have summarized that report in the next sections, a number of operational issues are not included for the sake of brevity.

Summary of Overall Protocol

The proposed quality management procedure consists of four steps. The first step consists of selecting the most suitable material or mix for a given project. The second step is dedicated to determining the variation in modulus with the primary parameter of interest and determining the target modulus. For base and subgrade materials, this step may consist of developing a moisture-modulus curve (similar to moisture-density curve). For a particular hot mix asphalt (HMA) mixture, this step may consist of developing air voids-modulus curve. In the third step, the variation in modulus with environmental factors is considered. For example, the variation in modulus with moisture of a base layer can be determined in the laboratory. In the case of a HMA layer, the variation in modulus with temperature is important. The fourth and final step is to compare the field modulus with the acceptable laboratory modulus. All steps are described below for the hot mix asphalt first, followed by granular materials.

Hot Mix Asphalt Protocol

Step 1: Selecting the Most Suitable Material

For the last century, the focus of the highway agencies has been towards placing the most durable pavement layers. For the most part, the characteristics of a durable material for a given layer depend on the collective experience of a large and diverse group of scientists and practitioners. For example, TxDOT specifications clearly define how to obtain a durable HMA material. Parameters, such as angularity of the aggregates, the hardness of aggregates, percent allowable fines, degree and method of compaction, all impact the modulus and strength of an HMA layer. However, the selection of acceptable levels for these parameters is for the most part experienced based. Very little effort has been focused to routinely define the impact of these parameters on the modulus of the layer.

Even though the durability of a material cannot be directly included in the structural design of a pavement, the durability definitely does impact the performance of that pavement. The process of volumetric design, from the simplest, Marshall Method, to the most sophisticated, Strategic Highway Research Program (SHRP) Method, ensures a constructible and durable material. As such, we cannot over-emphasize that the material selection and mix design should be based on the existing collective experience acquired by the highway community. The following steps, even though more quantitative, do not replace this knowledge.

Step 2: Selecting the Target Moduli

After the material is selected and its constructability is ascertained, the next step is to determine its modulus. For HMA materials, the modulus can be related to air voids similar to Figure 1. Two modulus values should be selected from the seismic modulus-air voids curves: the modulus corresponding to the air voids at placement (typically 8%), and the modulus at design air voids from the job mix formula (JMF, typically 4%). The modulus at placement is used by construction engineer for field quality control as described in Step 4. The modulus at the lab molded/JMF air void content can be used as a reference for the mix to ensure consistency of material supply and mix parameters.

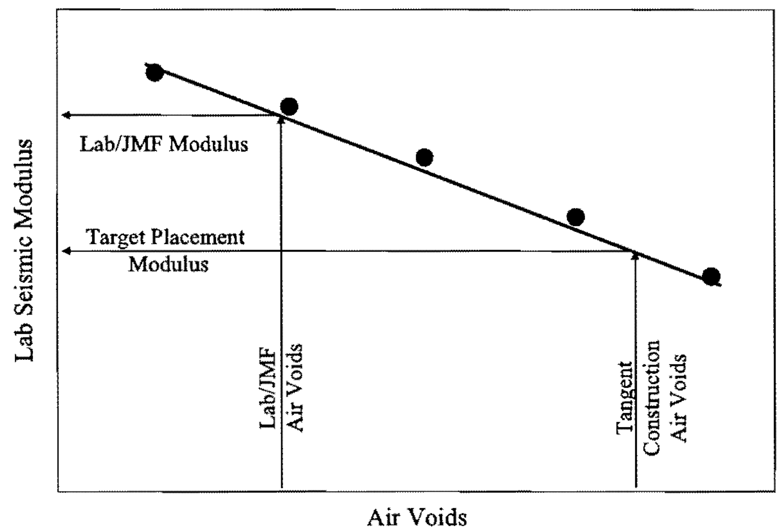


Figure 1. Process of Determining Field Target Moduli

Step 3: Characterizing the Variation in Modulus with Temperature

After the compaction of a layer is completed, it may be exposed to different temperatures. The simplest way of relating modulus to temperature consists of preparing two specimens: one at the JMF air voids and another at the target placement air voids. These specimens are subjected to a sequence of temperatures. The temperature range for the region being considered can be determined based on the guidelines set forward by SHRP for selecting the regional air temperature extremes to determine the appropriate PG grade for the binder. At the end of each temperature sequence, the specimens are tested as described in the next sections. An example for the variations in modulus with temperature for one mixture is shown in Figure 2.

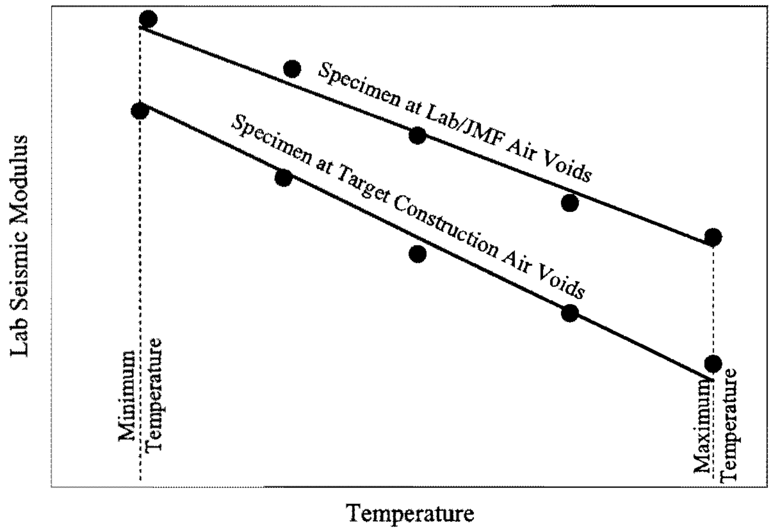


Figure 2. Process of Characterizing Variation in Modulus with Temperature

Step 4: Field Quality Control

Tests are carried out at regular intervals or at any point that the construction inspector suspects segregation, lack of compaction, or any other construction related anomalies. The field moduli should be greater than the target laboratory seismic modulus determined at the placement air voids in Step 2. An example is shown in Figure 3.

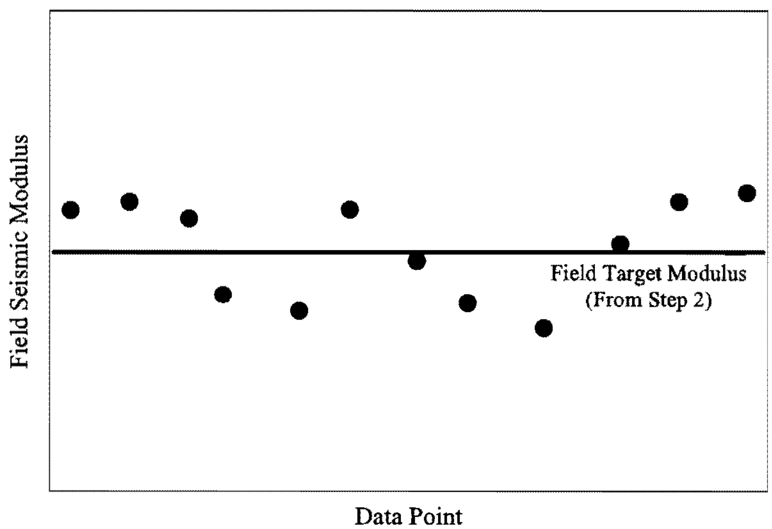


Figure 3. Process of Field Testing for HMA Materials

Protocol for Base and Prepared Subgrade

Step 1: Selecting Most Suitable Material

TxDOT specifications clearly define how to obtain a durable material. Parameters, such as the hardness of aggregates, percent allowable fines, allowable plasticity and degree and method of compaction, all impact the modulus and strength of a base layer. However, the selection of acceptable levels for these parameters is for the most part experienced based.

Step 2: Selecting the Target Moduli

After the material is selected and its constructability is ascertained, the next step is to determine its target field modulus. This modulus can be determined by relating seismic modulus to moisture content. In the normal development of a moisture density curve, several specimens with different moisture contents are prepared using the same compaction energy. The same specimens can be used to develop a moisture-modulus curve as shown in Figure 4. Typically, the maximum modulus is obtained at moisture content that differ from the traditional optimum moisture content. The seismic modulus at the traditional optimum moisture content can be estimated and used as the most suitable modulus. If the maximum seismic modulus is selected as the target field modulus, the moisture content at which the seismic modulus is obtained should be specified as the desired moisture content for construction.

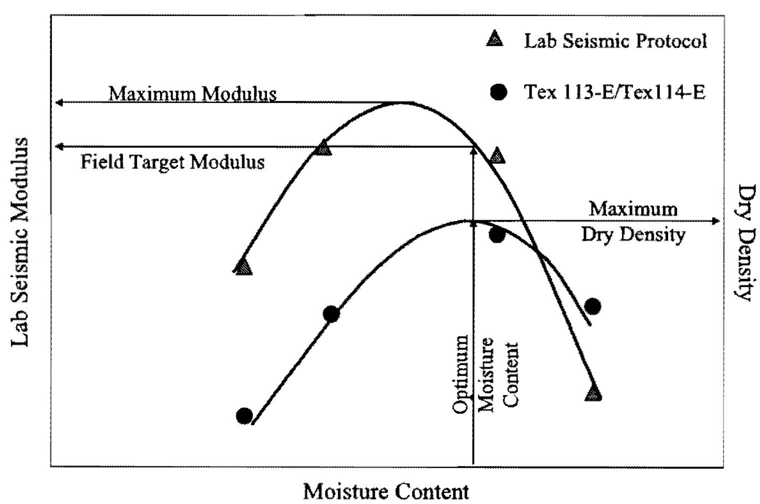


Figure 4. Process of Estimating Most Suitable Modulus

Step 3: Characterizing the Variation in Modulus with Moisture

Most base and subgrade materials may be exposed to different moisture regimes during their performance lives. The water retention potentials of some materials have shown to negatively impact their strength and stiffness parameters and, as such, their performance. To address this concern for base and subgrade materials, a specimen is prepared at the optimum moisture content and placed in an oven normally used for moisture content specimens and dried for at least four days (the drying cycle) at 140°F (60°C). The specimen is weighed, and tested daily. The specimen is then placed in a pan filled with water for six days (wetting cycle). The gain in weight of the specimen and the change in modulus with time are monitored daily. By inspecting the change in modulus with moisture content, the behavior of the material can be judged.

An example of variation in modulus with the time is shown in Figure 5. The drying cycle can be potentially associated with the change in the properties of the exposed soil during hot summer days after the completion of compaction. The wetting cycle can be related to the penetration of moisture into the base and subgrade layers either from surface cracks above or from the water table below. To incorporate the annual seasonal variation in modulus in the pavement design in a more systematic way, this modulus-moisture curve (see Figure 6) can potentially be used.

The other parameter that has been related to performance is the ratio of the residual modulus after the completion of the wetting cycle to peak modulus of the material after the completion of the drying cycle. These two moduli are defined in Figure 5.

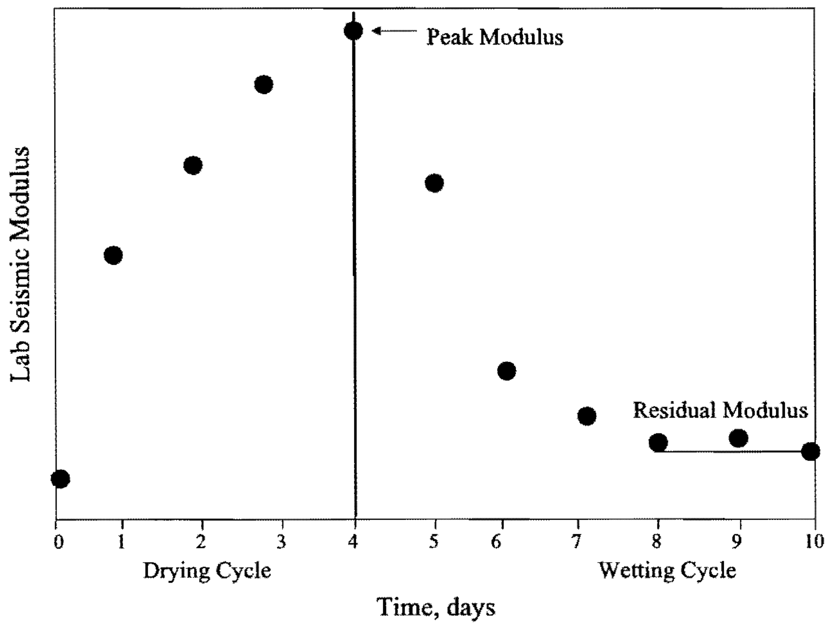


Figure 5. Variation in Modulus with Exposure to Moisture Process of Monitoring

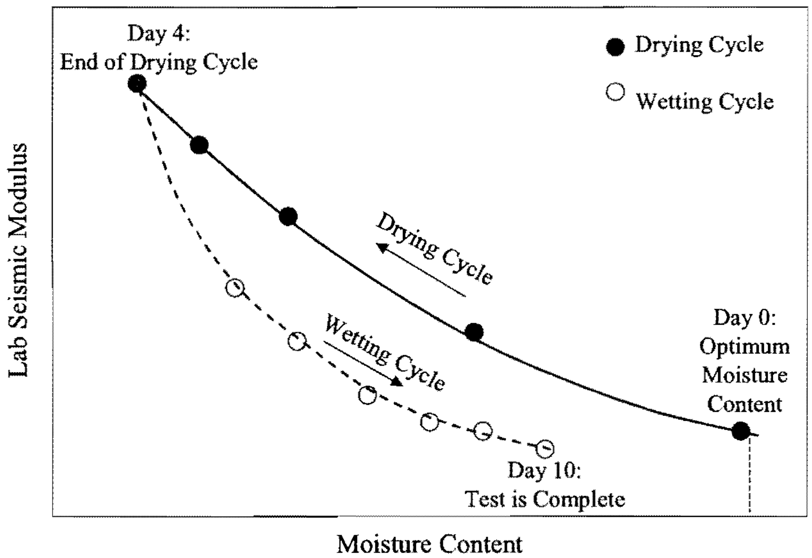


Figure 6. Process of Characterizing Variation in Modulus with Moisture

Step 4: Field Quality Control

Tests are carried out at regular intervals or at any point that the construction inspector suspects segregation, lack or excess moisture, or any other construction related anomalies. An example is shown in Figure 7. Similar to the statistical-based acceptance criteria used for moisture-density measurements, the field moduli should be greater than the target lab seismic modulus determined in Step 2.

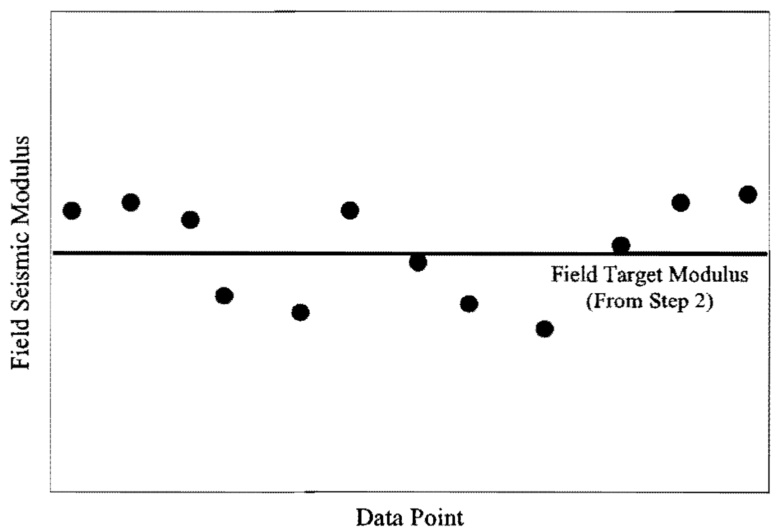


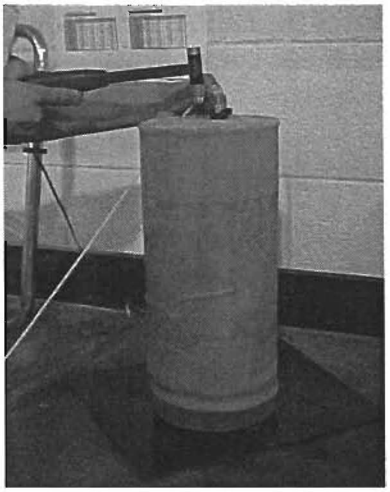
Figure 7. Process of Field Quality Control for Base and Subgrade Materials

Test Devices

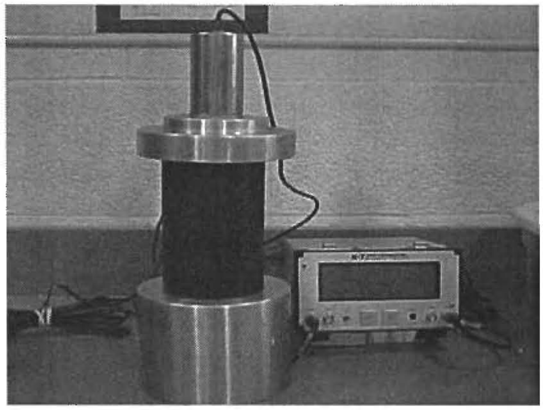
The focus of the study has been on measuring moduli with four inter-related devices. Two of these devices are used in the laboratory: the free-free resonant column device for testing base and subgrade specimens and the ultrasonic device for testing HMA cores and molded specimens. The other two devices are the Portable Seismic Pavement Analyzer (PSPA) for testing HMA layers nondestructively in the field and a version of it that works on the base and prepared subgrade materials (affectionately called DSPA for Dirt Seismic Pavement Analyzer). Each device is described below.

Free-free Resonant Column Test

The free-free resonant column (FFRC) test is a simple laboratory test for determining the modulus of pavement materials. When a cylindrical specimen is subjected to an impulse load at one end, seismic energy over a large range of frequencies will propagate within the specimen. Depending on the dimensions and the stiffness of the specimen, energy associated with one or more frequencies are trapped and magnified (resonate) as they propagate within the specimen. The goal with this test is to determine these resonant frequencies. Since the dimensions of the specimen are known, if one can determine the frequency(ies) that are resonating (i.e. the resonant frequencies), one can readily determine the modulus of the specimen.

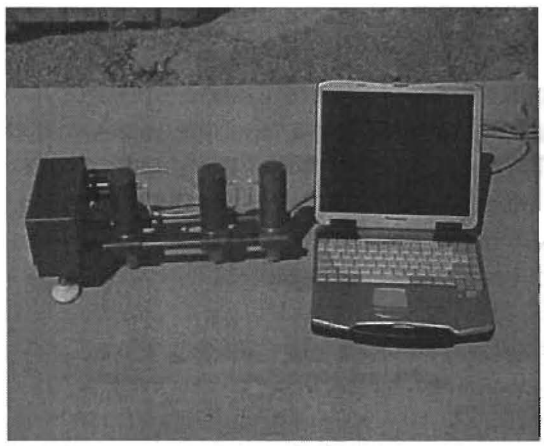


Ultrasonic Test Setup



The ultrasonic test methods were first used to evaluate the quality of concrete more than 50 years ago. The elastic modulus of a specimen is measured using a device (marketed as a V-meter) containing a pulse generator and a timing circuit, coupled with piezoelectric transmitting and receiving transducers. The timing circuit digitally displays the time needed for a wave to travel through a specimen. Knowing the travel time, the dimensions and the mass of the specimen, the modulus can be readily calculated.

Portable Seismic Pavement Analyzer



The Portable Seismic Pavement Analyzer (PSPA) is a device designed to determine the average modulus of a concrete or asphalt layer in the field. The PSPA consists of two receivers (accelerometers) and a source packaged into a hand-portable system, which can perform high frequency seismic tests. The device measures the velocity of propagation of surface waves that can be readily translated to a modulus. The PSPA has been modified so that it can be functional on base materials as well as prepared subgrade. This version of PSPA, which is affectionately called the Dirt SPA, DSPA, only differs in the source and some electronic components.

Protocols

In the next few sections the following test procedures are provided:

1. Determining Modulus of Base and Subgrade Materials with Free-Free Resonant Column
2. Determining Modulus of Asphalt-Concrete Specimens with Ultrasonic Pulse Velocity Method
3. Field Method for Determining In-Place Seismic Modulus of Soils and Base Materials
4. Field Method for Determining In-Place Seismic Modulus of HMA Materials

DETERMINING MODULUS OF BASE AND SUBGRADE MATERIALS WITH FREE-FREE RESONANT COLUMN

This test method provides a procedure for determining seismic modulus by means of the free-free resonant column (FFRC) method. The FFRC method is based on determining the velocity of propagation in the material.

The background behind the test method is included in the manual provided with the device.

Apparatus

- The free-free resonant column device consists of a data acquisition system, an instrumented hammer and an accelerometer.
- A balance with a capacity of 35 lb. (15 kg), accurate and readable to 0.5 g or 0.1% of the test mass, whichever is greater.
- Equipment to measure dimensions of specimen, accurate to 0.1 mm (0.004 in.)

Calibration

Calibration of the free-free resonant column device shall be verified prior to use on a project using a synthetic specimen provided with the device. If the measured modulus of the calibration specimen differs by more than 5% from established values, the manufacture shall be contacted.

Sample Preparation

Prepare standard 6-in. (150-mm) diameter specimens as per Test Method Tex-113-E procedure. A length-to-diameter ratio of 2 is desirable for specimens. However, tests can be performed on 6 in. (150 mm) by 8 in. (200 mm) specimens.

Procedure

The following table lists the steps necessary to determine the modulus of soils and base materials using the FFRC device.

Step	Action
1	Place the specimen on a rigid table top and measure the height and diameter of specimen. Note: The average of three diameter and height measurements is recommended.
2	Place the accelerometer securely on top of the specimen as discussed in the manual provided with the FFRC device.
3	Impact the top of the specimen with the instrumented hammer as discussed in the manual provided with the FFRC device.
4	Repeat Steps 2 and 3 three times at the same location
5	Record the average seismic modulus and density reported by the device Note: See FFRC manual for measurements and data interpretation.

Calculations

All calculations are performed automatically and are reported by the software during testing. An Excel^{TM} sheet is used to analyze and record the data upon completion of testing. The nature of these calculations is included in the manual provided with the device.

Part I: Determining the Relationship between Moisture Content and Seismic Modulus of Base and Subgrade Materials

Preparing Sample: Prepare the material according to Test Method Tex-101-E. Do not use previously laboratory compacted materials.

NOTE: For wetted stabilized materials taken from the roadway, see appropriate test method for preparation procedure for specification compliance, density, and/or modulus.

- Cement Stabilization: Test Method "Tex-120-E, Soil-Cement Testing"
- Lime Stabilization: Test Method "Tex-121-E, Soil-Lime Testing"
- Lime-Fly Ash Stabilization: Test Method "Tex-127-E, Lime-Fly Ash Compressive Strength Test Methods"

Procedure: The following table lists the steps necessary to determine the relationship between moisture content and the seismic modulus of base and subgrade materials.

Step	Action
1	Use the following test methods for the determination of optimum moisture content and maximum dry density of the material: • Test Method Tex-113-E, Base Material • Test Method Tex 114-E, Subgrade Do not discard the specimens
2	Cover the specimens prepared in Step 1 to avoid moisture loss. Allow each specimen to cure at room temperature for 24 ± 4 hours. Note: The specimens can be enclosed in plastic wrap or preferably covered with a latex membrane used in triaxial testing described in Test Method Tex-118-E.
3	Conduct the free-free resonant column (FFRC) test on each specimen as per Test Method Tex-147-E. Record the seismic modulus for each specimen.
4	Develop a Modulus-Moisture curve, as seen in Figure 1. Note: It would be desirable to superimpose the moisture-density and moisture modulus curves on one graph. Typically, the maximum modulus is obtained at a moisture content which is dry of traditional optimum moisture content obtained in Step 1.

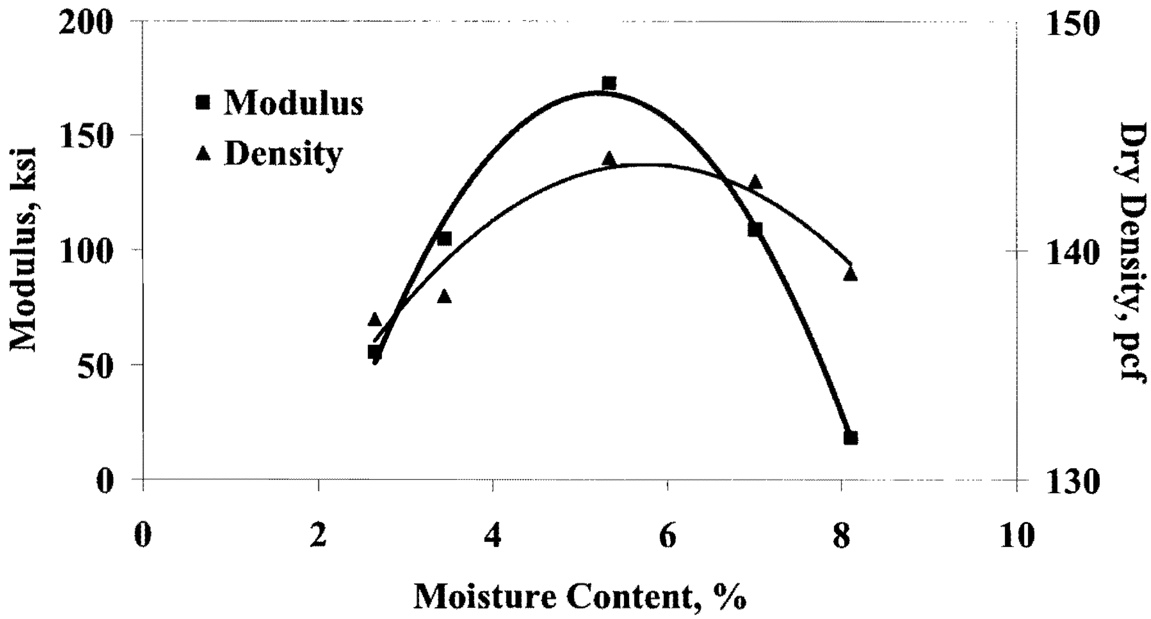


Figure 1 – Example Variations in Modulus and Dry Density with Moisture Content.

Report Test Results:

- Plot of Moisture Content in percent vs. Dry Density in pcf (Kg/m^3).
- Maximum Dry Density. in pcf (Kg/m^3)
- Moisture Content at Maximum Dry Density in percent.
- Plot of Moisture Content in percent vs. Seismic Modulus in ksi (MPa).
- Maximum Seismic Modulus in ksi (MPa).
- Moisture Content at Maximum Seismic Modulus in percent

Part II: Determining the Peak and Residual Moduli of Base and Soil Materials After Drying and Partial Saturation

Preparing Sample: Prepare the material according to Test Method Tex-101-E. Do not use previously laboratory compacted materials.

Procedure: The following table lists the steps necessary to determine the peak and residual seismic moduli of base and subgrade materials.

Step	Action
	Specimen Preparation
1	Trim a cylindrical plastic concrete mold to obtain a height of 8 ¼ in. (203 mm). At approximately ¼ in. (6 mm) above the outside bottom of the mold, drill 1/16 in. (1 mm) diameter holes around the circumference of the mold at a horizontal spacing of ½ in. (12 mm). This equates to about 40 holes around the mold base. Weigh the cylinder mold and record as W_{mold} in lb. (Kg). Note: Alternatively, a Texas Triaxial Cell can be used to store the specimen.
2	Compact a specimen at optimum moisture and maximum dry density in accordance with Test Method Tex-113-E or Test Method Tex-114-E in the mold. Record the initial moisture content, w_i, in percent. Note: The specimens should be 6 in. (152 mm) in diameter and 8 ± 0.25 in. (203 ± 7 mm) in height. The surface of each specimen should be made as smooth and level as possible after compaction.
3	Record the weight as initial weight of specimen and mold, W_i in lb. (Kg). Also, record the time (hr:min) that the compaction of specimen is completed.
4	Perform the free-free resonant column (FFRC) test on the specimen and record obtained modulus.
	Drying Cycle
5	Place specimen in an oven maintained at 140 ± 5 °F (60 ± 3 °C) for 96 ± 4 hours.
6	Every 24 ± 4 hours take out the specimen from the oven and allow it to cool down at room temperature for approximately one hour. Conduct the FFRC test on the specimen. Record the weight of the specimen and mold as W_n in lb. (Kg). Also measure and record the seismic modulus of the specimen and the time of testing.

Step	Action
Wetting Cycle	
7	Place the specimens in a flat-bottomed pan on a level surface. Fill the pan with tap water to a depth of 1 ± 1/8 in. (25 ± 3mm). The moisture bath should be maintained at this depth throughout the test period.
8	Every 24 ± 4 hours take out the specimen from the water. Allow the excess water to drain. Conduct the FFRC test on the specimen. Record the weight of the specimen and mold as W_n in lb (Kg). Also measure and record the modulus of the specimen and the time of testing.
9	The test is completed when the elapsed time exceeds 240 hours after compaction.
10	Plot the variation in modulus and moisture content with time for drying and wetting cycles as seen in Figure 1.

Calculations:

- Calculate the percent moisture content at day n, (w_n)

$$w_n = w_i + \left(\frac{W_n - W_i}{W_i - W_{mold}} \right)(100 - w_i)$$

  - W_n = wet weight of the sample and mold at day n, lb. (Kg)
  - W_i = wet weight of the sample and mold at day zero, lb. (Kg)
  - W_{mold} = mass of mold, lb. (Kg)
  - w_i = initial moisture content, %

Note: The calculations return the same answer if Kg is used as the measurement of mass instead of using weight, but the measurement units must be consistently used throughout the calculations.

Report Test Results:

- Seismic modulus after 24 hours, ksi (MPa)
- Peak seismic modulus (modulus at completion of drying phase), ksi (MPa)
- Residual seismic modulus (average moduli of the last four days of wetting phase), ksi (MPa)

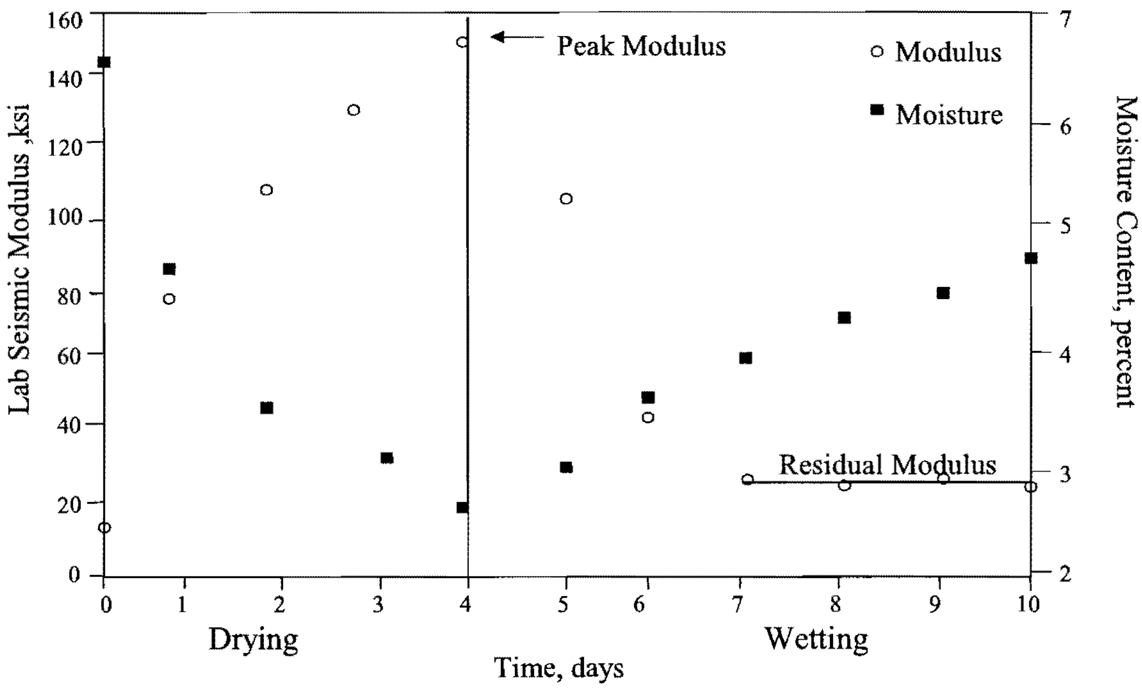


Figure 1: Plot of Modulus and Moisture Content with Time

DETERMINING MODULUS OF HOT MIX ASPHALT SPECIMENS WITH ULTRASONIC PULSE VELOCITY METHOD

This test method provides a procedure to determine the seismic modulus by means of the ultrasonic pulse velocity method. This method determines the velocity of propagation of ultrasonic energy pulse, through the material.

Apparatus

- The ultrasonic device consists of a pulse generator and a timing circuit, coupled with piezo-electric transmitting and receiving transducers.
- A balance with a capacity of 35 lb (15 kg), accurate and readable to 0.001 lbs (0.5 g) or 0.1% of the test specimen's weight, whichever is greater.
- Equipment to measure specimen dimensions, accurate to 0.1 mm (0.004 in.)
- Temperature measuring device precise to closest 1°F (0.5°C).

Sample Preparation

Prepare laboratory molded specimens according to "Tex-206-F, Compacting Specimens Using the Texas Gyratory Compactor (TGC)" or "Tex-241-F, Superpave Gyratory Compacting of Test Specimens of Bituminous Mixtures." Alternatively, cores with smooth ends can be tested.

Calibration

Calibration of the device shall be verified prior to use on a project using a synthetic specimen provided with the device. If the measured modulus of the calibration specimen differs by more than 2 microseconds from the established values, the manufacture shall be contacted.

Procedure

1	Record the diameter in in. (mm), height in in. (mm), and weight in lb (Kg) for each specimen. Note: For roadway cores, the average of three diameter and height measurements is recommended.
2	Place dampening pads on both transducers with grease to ensure full contact between the transducers and specimen.
3	♦ Place the transducers at opposite ends of the specimen. ♦ Apply firm pressure to the specimen with the transducers.
4	♦ Make sure that the travel time exhibited is stable. ♦ Record the travel time and repeat step 3 for the next specimen. Note: In order to take a more representative wave travel-time, take an average of four readings by changing the location of the transmitter and receiver.
5	Measure the temperature of the specimen in degree F (degree C) for temperature adjustment.

Calculations

The modulus is calculated in customary unit from:

$$E_V = 3.295\,x\,10^6\,x\,\frac{WH}{D^2 t_v^2}\,x\,\frac{(1+\nu)(1-2\nu)}{(1-\nu)}$$

and in SI units from:

$$E_V = 1.274\,x\,10^9\,x\,\frac{WH}{D^2 t_v^2}\,x\,\frac{(1+\nu)(1-2\nu)}{(1-\nu)}$$

where:

- E_V = modulus, ksi (MPa)
- H = Height of specimen, in. (mm)
- W = Weight of specimen, lbs (Kg)
- D = Diameter of specimen, in. (mm)
- t_v = Average travel time, microseconds
- υ = Poisson's ratio. If it is not available, use default value of 0.4.

Part I: Selecting Target Modulus

Procedure: The following table lists the steps necessary to determine the target modulus for a given material. Note that the mix design should be carried out according to "Tex-204-F, Design of Bituminous Mixtures."

Step	Action
1	Mold five specimens at Optimum Asphalt Content (OAC) according to "Tex-241-F, Superpave Gyratory Compacting of Test Specimens of Bituminous Mixtures." • Specimens must be molded at different percent air voids. The preferred range is between 2 % to 12 %. • Specimens must have similar heights, within ± 0.1 in. (± 2 mm) of each other. Note1: For mixtures designed using the Texas Gyratory Compactor, adjust the sample weight to obtain different percent air voids. Note2: For mixtures designed using the Superpave Gyratory Compactor, use less and more gyrations than N_{design} using N_{inital} and $N_{maximum}$ as guidelines. Note3: Do not calculate percent air voids at this point.
2	♦ Let the specimens cool to room temperature (77 ± 9 °F, 25 ± 5 °C) for 24 ± 4 hours. ♦ Measure the temperature of the specimen in degrees F (degrees C) for temperature adjustment.
3	Determine the seismic modulus of each specimen by using the ultrasonic device.-
4	Measure the air voids of each specimen according to Tex-207-F, Determining Density of Compacted Bituminous Mixtures.
5	Develop a seismic modulus-air voids relationship as shown in Figure 1.

Report

- Seismic modulus at design air voids in ksi (MPa)
- Seismic modulus at the target air voids expected during construction in ksi (MPa)
- Plot of modulus in ksi (MPa) vs. percent air voids.

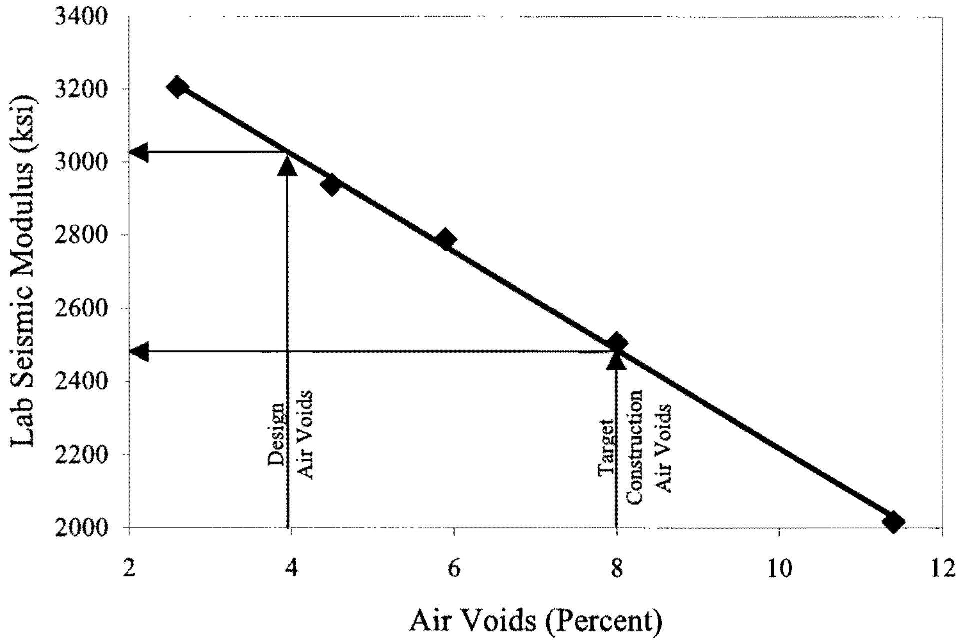


Figure 1 – Typical Seismic Modulus vs. Air Voids

Part II: Characterizing Variation in Modulus with Temperature

Procedure: The following table lists the steps necessary to relate modulus to temperature.

Step	Action
1	Prepare one specimen at the lab/JMF design air voids and one at the target air voids expected during construction. NOTE: Specimens from Part I may be reused.
2	♦ Subject the specimens to a sequence of temperatures. The range of temperature can be obtained using the guidelines used to specify the PG binder used in the mixture. ♦ Use the nominal temperature range from 30°F to 130°F at nominal 20°F intervals (0°C to 50°C at 10°C intervals). ♦ Maintain the specimen in the temperature-controlled oven or bath for at least two hours at each temperature. NOTE: A dummy specimen equipped with a thermocouple embedded at mid-height and the center of the specimen is recommended to ensure temperature equilibrium in each specimen. If a temperature bath is used, the specimens should be protected from moisture by placing them in watertight zip-lock bags, following the Corelok procedure or other suitable waterproofing technique.
3	As soon as the specimen's temperature is equalized to the desired temperature, calculate the average seismic modulus according to "Tex-254-F, Determining Modulus of Hot Mix Asphalt Specimens with Ultrasonic Pulse Velocity Method."
4	Report the average seismic modulus at each temperature for each specimen.
5	Develop a modulus-temperature relationship as shown in Figure 2.

Report Test Results:

- Plot of modulus in ksi (MPa) vs. temperature in degree F (C)
- Best-fit curve parameters for seismic modulus vs. temperature at Lab/JMF air voids from worksheet provided with the device. The equation is in the form of:

  $$E_{seismic} = \alpha T + \beta$$

  where Eseismic is the seismic modulus, and T is the temperature. Parameters α and β are determined from the best-fit curve.

- Best-fit curve parameters for seismic modulus at the target air voids expected during construction following the same equation as the previous item.

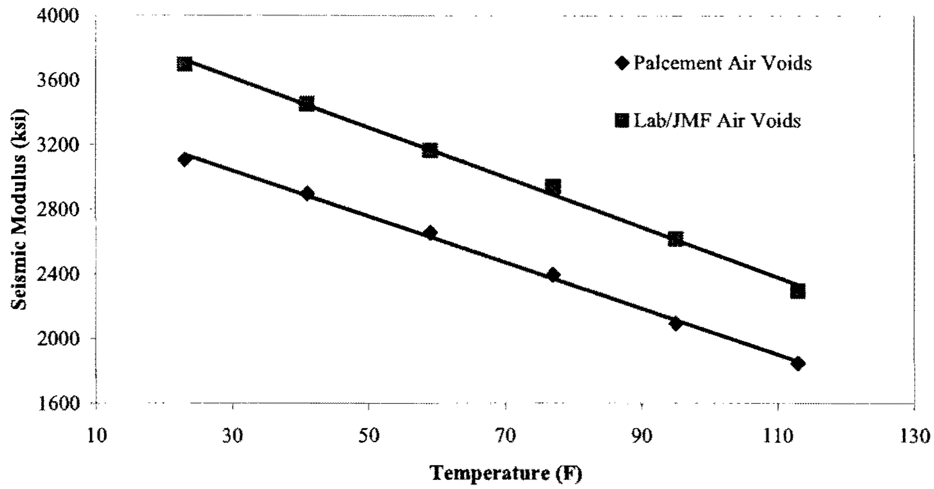


Figure 2 – Seismic Modulus vs. Temperature

Field Method for Determining In-Place Seismic Modulus of Soils and Base Materials

This method determines the seismic modulus of untreated and treated soil and granular material compacted in the roadway using a version of the Portable Seismic Property Analyzer (PSPA) affectionately called the dirt SPA or (DSPA).

The in-place seismic modulus is then compared with the target modulus obtained from method Test Method Tex-147-E entitled “Determining Modulus of Base and Subgrade Materials with Free-Free Resonant Column (FFRC) Method.”

The term "soils" used in this procedure includes all base materials, as well as fine grain soils.

Apparatus

The following apparatus is required:

- Dirt Seismic Pavement Analyzer (DSPA)
- Straightedge and miscellaneous hand tools

Procedure

The following table lists the steps necessary to determine in-place modulus of soils and base materials using the PSPA.

Step	Action
1	Prepare the test area by creating a surface free of loose material.
2	Place the DSPA on the prepared surface so that the source and the receivers are seated in full contact with the soil or base material. Note: Avoid any area with desiccation or any other type of cracks
3	After seating the DSPA, activate the software.
4	Input the type of material being tested and the desired depth of measurement into the software.
5	Record the average seismic modulus reported by the device
6	Rotate the DSPA 90 degrees and repeat.

Calculations

Read the seismic modulus directly.

Reporting Test Results

Report average modulus to the nearest 1 ksi.

Notes

The instruction manual furnished with the DSPA should be followed for specific operation of it.

Field Method for Determining In-Place Seismic Modulus of HMA Materials

This method determines the seismic modulus of compacted hot mix asphalt (HMA) layer in the roadway using the Portable Seismic Pavement Analyzer (PSPA).

The in-place seismic modulus is then compared with the target modulus obtained from method Test Method Tex-254-E entitled Estimating Modulus of Hot Mix Asphalt Specimens with Ultrasonic Pulse Velocity Method.

Apparatus

The following apparatus is required:

- Portable Seismic Pavement Analyzer (PSPA)

Procedure

The following table lists the steps necessary to determine in-place modulus of HMA materials using the Portable Seismic Pavement Analyzer for quality management

Step	Action
1	Prepare the test area by creating a surface free of loose materials.
2	Place the PSPA on the prepared surface so that the source and the receivers are seated in full contact with the HMA layer. Note: Avoid any cracked area.
3	After seating the PSPA, activate the software.
4	Input the type of material being tested as HMA and the thickness of the layer into the software.
5	Record the average seismic modulus and surface temperature reported by the device.
6	Rotate the gauge 90 degrees and repeat.

Calculations

Read the seismic modulus and surface temperature directly.

Reporting Test Results

Report average modulus to the nearest 1 ksi, and surface temperature to nearest degree F.

Notes

- The instruction manual furnished with the PSPA should be followed for specific operation of it.