HMEC

Highway Materials Engineering Course

PARTICIPANT WORKBOOK

LABORATORY MANUAL

Performance Testing

MODULE

F

U.S.Department of Transportation
Federal Highway Administration

Contents

Laboratory Safety

Personal Protective Equipment

All participants in the laboratory experience must wear the following safety equipment at all times:

- Safety glasses
- Safety shoes or shoe covers
- Other safety equipment may be necessary for certain tests

Hazard Exposures

Chemical exposures in the laboratory include the following. Please see safety data sheets (SDSs) for more information on each of these substances.

- Excel Clean HD (a citrus-based cleaner)
- Asphalt

Asphalt

Copies of the SDSs for each of these substances will be provided to course participants and will be available in a yellow folder at the entrance to the AMRL laboratory.

Heat

Asphalt binder and ovens will be heated to temperatures of approximately 163°C (325°C). Heat-resistant gloves must be worn when working with hot asphalt samples and putting materials in or retrieving them from the ovens.

Ensuring Your Safety

For your safety, please follow all instructions provided by the laboratory instructors. Do not touch or handle equipment unless you have been given permission to do so.

Laboratory Procedures and Time Needed to Complete

Standard Designation	Test Name	Total Time	Hands-on Time
AASHTO T 321	Determining the Fatigue Life of Compacted Hot Mix Asphalt (HMA) Subjected to Repeated Flexural Bending	7-13 hours	4 hours
AASHTO T 322	Standard Method of Test for Determining the Creep Compliance and Strength of Hot Mix Asphalt (HMA) Using the Indirect Tensile Test Device	1-2 days	6 hours
AASHTO T 324	Hamburg Wheel-Track Testing of Compacted Hot-Mix Asphalt (HMA)	13-33 hours	6 hours
AASHTO TP 79	Standard Method of Test for Determining the Dynamic Modulus and Flow Numbers for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)	43 hours	4 hours

AASHTO T 321, Determining the Fatigue Life of Compacted Hot Mix Asphalt (HMA) Subjected to Repeated Flexural Bending

Background Information

Fatigue cracking occurs when repeated traffic loads cause sufficient damage to HMA pavements. The pavement structure as a whole eventually cracks under the repeated loads. The determining factors for this fatigue life are structure, bonding, stiffness, and support.

Significance and Use

The performance of HMA pavements can be better predicted using this test by showing the effects of repeated flexural bending and the correlation to fatigue life.

Related Tests and Specifications

- AASHTO PP 3, Preparing Hot Mix Asphalt (HMA) Specimens by Means of the Rolling Wheel Compactor
- AASTHO T247, Preparation of Test Specimens of Hot Mix Asphalt (HMA) by Means of California Kneading Compactor
- ASTM D 5361, Standard Practice for Sampling Compacted Bituminous Mixtures for Laboratory Testing

Timeline for Completion

Prep Time: 6 – 12 hours

Samples are laboratory compacted or field obtained as slabs or cylindrical and mounted into the testing molds/apparatus

Time to Perform Procedure: 20 – 40 minutes

An initial run of 50 cycles at 5 to 10 Hz is conducted on the specimen prior to the test of at least 10,000 cycles at the same frequency

Calculations: 5 – 20 minutes

Usually software produced, report the initial flexural stiffness, the cycles to failure, a plot of stiffness vs. load cycles, and a plot of dissipated energy vs. load cycles

TOTAL TIME: 7 – 13 hours

Apparatus

Testing system (Figure 1)

Loading Device – closed-loop, computer controlled loading system that adjusts and applies loads such that the specimen experiences a constant level of strain during each load cycle. Operates at a frequency of 5 to 10 Hz with a four-point system.

Environmental Chamber (Optional) – Maintains the specimen at 20.0 ± 0.5 °C. Only necessary if the surrounding environment cannot maintain this temperature range.

Control and data acquisition system – Records load cycles, applied loads, and beam deflections then computes the maximum tensile stress, maximum tensile strain, phase angle, stiffness, dissipated energy, and cumulative dissipated energy.

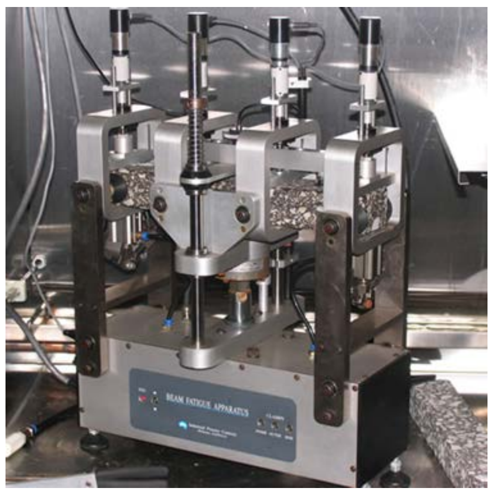


Figure 1: Beam Fatigue Apparatus

Sample Preparation

Step 1

Prepare three replicate beams specimens from slabs (compacted by AASHTO PP3), beams (compacted by ASTM D3202), or sampled from the roadway by ASTM D5361.

Note: The type of compaction device may influence the test results. It is recommended to cut beams from a large slab compacted by a vibratory roller.

Step 2

Specimen ends should be cut parallel by sawing at least 6 mm from the sides. The final dimensions afer sawing should be 380 ± 6 mm in length, 50 ± 6 mm in height, and 63 ± 6 mm in width.

Step 3
Some loading device requires a nut affixed to the sides of the sample for deformation readings. Attach with epoxy to the center point of one of the sides and allow to cure before moving the specimen.

Procedure

Step 1
Place the specimen in an environmental chamber that is at 20.0 ± 0.5°C for 2 h to ensure the specimen is at the test temperature prior to beginning the test.

Step 2
Open the clamps and slide the specimen into position.

Step 3
Ensure proper horizontal spacing of the clamps, 119 mm center-to-center.

Step 4
When the specimen and clamps are in the proper positions, close the outside clamps by applying sufficient pressure to hold the specimen in place. Next, close the inside clamps by applying sufficient pressure to hold the specimen in place.

Step 5
Attach the LVDT to the specimen.

Step 6
Select the desired initial strain (250 to 750 microstrain) and loading frequency, and the load cycle intervals at which test results are recorded and computed and enter them into the recording and control component's test program. Set the loading frequency within a range of 5 to 10 Hz.

Step 7
Apply 50 load cycles at a constant strain of 250 to 750 microstrain.

Determine the specimen stiffness at the 50th load cycle.

This stiffness is an estimate of the initial stiffness, which is used as a reference for determining specimen failure.

Note: In some instances, with highly modified materials for specialized applications, testing has been conducted with initial peak-to-peak strains as high as 2000 microstrain.

Step 8

Select a deflection level (strain level) such that the specimen will undergo a minimum of 10,000 load cycles (but can be as high as 1 million) before its stiffness is reduced.

A minimum of 10,000 load cycles ensures that the specimen does not decrease in stiffness too rapidly.

Step 9

Begin the test.

Step 10

For each load cycle at which data are collected, compute the product of the flexural stiffness and load cycles (S × n)

S is the stiffness as calculated below, and n is the number of cycles completed.

Step 11

Terminate the data collection and stop the test after a point where the computed (S × n) has reduced from a peak value by 15 percent.

Calculations

Step 1

Maximum Tensile Stress (Pa): $\sigma_t = \frac{0.375P}{bh^2}$

Where:

P = applied load (N)

b = average beam width (m)

h = average beam height (m)

Step 2

Maximum Tensile Strain (m/m): $\varepsilon_t = \frac{12\delta h}{3L^2 - 4a^2}$

Where:

δ = applied load (N)

h = average beam height (m)

L = beam length between outside clamps (0.357 m)

a = space between inside clamps (0.119 m)

Step 3

Flexural Stiffness (Pa): $S = \frac{\sigma_t}{\varepsilon_t}$

Phase Angle: $\varphi_t = 360fs$

Where:

f = load frequency (Hz)

s = time lag between maximum load and deflection (s)

Step 4

Dissipated Energy per Cycle J/m^3: $D = \pi\sigma_t\varepsilon_t \sin(\varphi_t)$

Where:

σt = maximum tensile stress (Pa)

εt = maximum tensile strain (m/m)

ϕt = phase angle (degrees)

The cumulative dissipated energy is then the sum of the dissipated energy for each load cycle.

Reporting the Test Results

Step 1
Hot Mix Asphalt Description—Report the binder type, binder content, aggregate gradation, and air void percentage.

Step 2
Specimen Dimensions—Report the specimen length, average specimen height, and average specimen width in meters to four significant figures.

Step 3
Report the average test temperature to the nearest 0.2°C.

Step 4
Report the test results listed in Table 2 for each load cycle interval selected by the operator to three significant figures.

Step 5
Report the initial flexural stiffness in pascals.

Step 6
Report the cycles to failure.

Step 7
Prepare a plot of stiffness versus load cycles as shown in Figure 2.

Step 8
Prepare a plot of dissipated energy versus load cycles as shown in Figure 3.

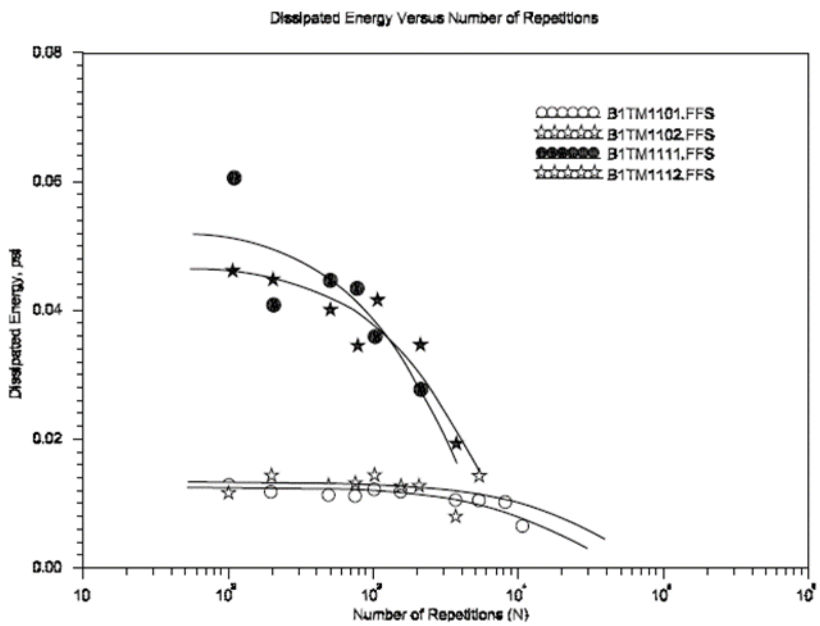


Figure 2: Dissipated Energy versus Load Cycles

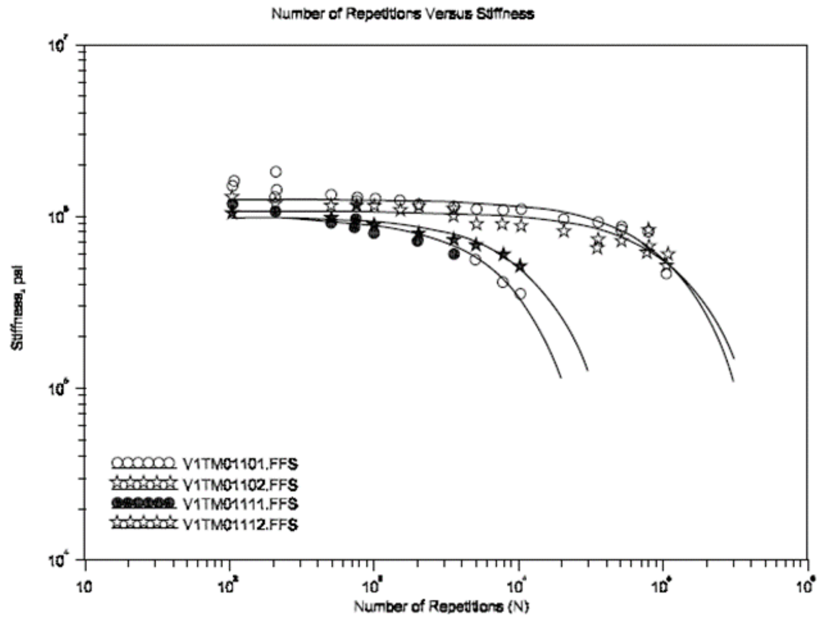


Figure 3: Stiffness versus Load Cycles

AASHTO T 322, Standard Method of Test for Determining the Creep Compliance and Strength of Hot Mix Asphalt (HMA) Using the Indirect Tensile Test Device

Background Information

A specially designed indirect tensile (IDT) system with an environmental chamber are used to apply a static load along the diametral axis of a HMA specimen. The IDT creep and strength test was developed during the Strategic Highway Research Program (SHRP) to address the need for characterizing the low-temperature thermal cracking of HMA samples.

Significance and Use

The creep compliance and IDT strength of HMA provide the data necessary for low temperature thermal cracking analysis. Creep compliance is defined as time-dependent strain per unit stress, and IDT strength is best defined as HMA strength when subjected to tension.

Related Tests and Specifications

- AASHTO PP 3, Hot Mix Asphalt (HMA) Specimens by Means of the Rolling Wheel Compactor
- AASHTO T 312, Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor
- ASTM D5361, Standard Practice for Sampling Compacted Bituminous Mixtures for Laboratory Testing
- ASTM D4123, Standard Test Method for Indirect Tension Test for Resilient Modulus of Bituminous Mixtures (Withdrawn 2003)
- AASHTO T 166, Bulk Specific Gravity (Gmb) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
- AASHTO T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
- ASTM D5361, Standard Practice for Sampling Compacted Bituminous Mixtures for Laboratory Testing
- AASHTO T 320, Determining the Permanent Shear Strain and Stiffness of Asphalt Mixtures Using the Superpave Shear Tester (SST)

Timeline for Completion

Prep Time: 24–48 hours

Specimens are laboratory compacted or field obtained, refined, and measured. The bulk specific gravity is obtained, the specimen is dried, and the displacement transducers mounted.

After set-up is complete, the specimen is conditioned at test temperature for 2 to 4 hours before being tested.

Time to Perform Procedure: 15 minutes

Calculations: 15 minutes

Calculate the creep compliance D(t).

TOTAL TIME: 1–2 days

Apparatus

Figure 4: IDT test system and environmental chamber

Indirect tensile testing system – The axial loading device, load measure device, specimen deformation measurement devices, environmental chamber, and control/data acquisition systems as specified in Section 6 of AASHTO T 322. (Figure 4)

Gauge points – Eight brass gauge points having a diameter of 8 mm and a height of 3.2 mm required per specimen. A view of these mounted to a specimen are in Figure 5.

Mounting template – Used for mounting the gauge points to the specimen. (Figure 6)

Test specimen loading frame – As described in ASTM D4123. Delivers test loads in diametral plane, as seen in Figure 5.

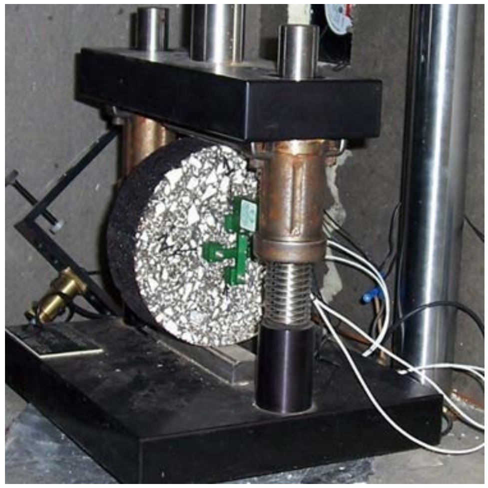


Figure 5: A closer view of the specimen mounted with the gauge points in the test specimen loading frame

Sampling

A minimum of three specimens should be obtained by laboratory molding (AAHSTO T 312 or AASHTO PP 3) or from roadway specimens in accordance with ASTM D5361.

Sample Preparation

Step 1
Ensure smooth, parallel sides by cutting at least 6 mm with a saw. Specimen dimensions should be 38 to 50 mm in height and 141 to 159 mm in diameter.

Step 2
Determine and record the height and diameter of each specimen in accordance with ASTM D3549, and the bulk specific gravity in accordance with AASHTO T 166.

Step 3
Dry the specimens at room temperature to constant mass.

Step 4
Mount the brass gauge points to each of the specimens with epoxy according to the pattern shown on the mounting plate in Figure 6. The placement and location of the gauge points on each face shall produce a mirror image of each other.

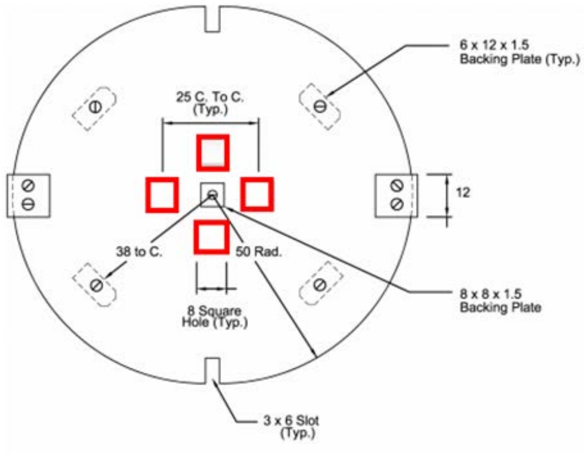


Figure 6: Mounting plate with pattern for brass gauge points

Procedure

Step 1
Mount the specimen on the loading frames in the environmental chamber.

Step 2
Lower the temperature of the environmental chamber to the test temperature and, once the test temperature ± 0.5 °C is achieved, allow each specimen to remain at the test temperature from 3 ± 1 hour prior to testing.

Note: Under no circumstances shall the specimen be kept at 0 °C or less for more than 24 hours.

Step 3
Zero or rebalance the electronic measuring system and apply a static load of fixed magnitude (± 2%) without impact to the specimen for 100 ± 2 seconds. If a complete analysis is required, a period of 1,000 ± 20.5 seconds has been found suitable.

Note: If either limit is violated, stop the test and allow a recovery time of 5 minutes before restarting with an adjusted load.

Step 4
Use a fixed load that produces a horizontal deformation of 0.00125 mm to 0.0190 mm for 150-mm diameter specimens.

Step 5
Record the vertical and horizontal deformations.

Step 6
After completion of the creep testing, the tensile strength is determined by applying a load to the specimen at a rate of 12.5 mm per minute.

Step 7
Record the horizontal and vertical deformations, as well as the load on the specimen, until the load decreases.

Step 8
Determine the tensile creep compliance of each of the three specimens at three measurements at 10 °C intervals. Section 11.1 gives recommended temperature test points.

Calculations

Step 1
Calculate the air voids for each specimen according to AASHTO T 269.

Step 2
Calculate the average for the three specimens of the thickness (b_{avg}), diameter (D_{avg}), and creep load (P_{avg}).

Step 3
Compute the normalized horizontal and vertical deformation arrays for each of the six specimen faces as in Section 12.2.3.

Step 4
Obtain the average horizontal and vertical deformation at a time corresponding to one-half of the total creep test time for each of the six specimen faces as in Section 12.2.4 (i.e., for a 100-second test, obtain the deformations at t = 50 seconds).

Step 5
Obtain the trimmed mean of the deflections by dropping the highest and lowest values and averaging the middle four values for the horizontal (ΔXt) and vertical deformations (ΔYt).

Step 6

Obtain the ratio of the horizontal to vertical deformations, $\frac{X}{Y}$, from $\Delta X_t/\Delta Y_t$.

Step 7
Compute the creep compliance $(kPa)^{-1}$, D(t):

$$D(t) = \frac{\Delta X_{tm,t} \text{ x } D_{avg} \text{ x } b_{avg}}{P_{avg} \text{ x } GL} \times C_{cmpl}$$

where:

$\Delta X_{tm,t}$ = Trimmed mean of the horizontal ($\Delta_{Xi,t}$) arrays

GL = gauge length in meters (38 x 10^{-3} for 150-mm diameter specimens)

C_{cmpl} = $0.6354 \times (\frac{X}{Y})^{-1} - 0.332$

Where: $\left[0.704 - 0.213\left(\frac{b_{avg}}{D_{avg}}\right)\right] \leq C_{cmpl} \leq \left[1.566 - 0.195\left(\frac{b_{avg}}{D_{avg}}\right)\right]$

Step 8

Poisson's ration, ν, may be computed as: $\nu = -0.10 + 1.480\left(\frac{X}{Y}\right)^2 - 0.778\left(\frac{b_{avg}}{D_{avg}}\right)^2\left(\frac{X}{Y}\right)^2$

where $0.05 \leq \nu \leq 0.50$

Step 9
Compute the tensile strength (nearest pascal) for each specimen, $S_{t,n}$:

$$S_{t,n} = \frac{2 \times P_{f,n}}{\pi \times b_n \times D_n}$$

where:

$P_{f,n}$ = maximum load observed for specimen, n

$S_{t,n}$ = tensile strength of specimen, n (Pa)

Step 10
Compute the average tensile strength.

Note: Most of the calculations are usually completed by software specifically designed for AASHTO T 322.

Reporting the Test Results

Report the bulk specific gravity, maximum specific gravity, the air voids, the height and diameter, test temperature, and the creep load for each test specimen. The calculated tensile creep compliance values D(t), in kPa, and tensile strength (σt), to the nearest pascal should be reported for each specimen as well as the average.

AASHTO T 324, Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt (HMA)

Background Information

The Hamburg Wheel Tracking Device was developed in Germany. Prepared specimens are repetitively loaded using a reciprocating, weighted steel wheel while submerged in a temperature controlled bat of 40 to 50 °C (104 to 122°F). The deformation caused by the wheel is measured and reported as pass/fail based on specifications.

Significance and Use

The Hamburg (Immersion) wheel tracking test is used to evaluate the resistance to rutting and moisture susceptibility of asphalt mixtures. Susceptibilities to rutting and moisture are typically based on pass/fail criteria.

Related Tests and Specifications

- AASHTO R 30, Mixture Conditioning of Hot Mix Asphalt (HMA)
- AASHTO T 166, Bulk Specific Gravity (Gmb) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
- AASHTO T 209, Theoretical Maximum Specific Gravity (Gmm) and Density of Hot Mix Asphalt (HMA)
- AASHTO T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
- AASHTO T 312, Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

Timeline for Completion

Prep Time: 6-26 hours

Specimens are either compacted or field obtained then mounted in the testing apparatus.

Time to Perform Procedure: 6.5 hours

After a 30 minute equilibration period, the specimens are subjected to 20, 000 passes of the steel wheel.

TOTAL TIME: 13-33 hours

Apparatus

Hamburg Wheel-Track testing machine (as shown in Figure 7) – Capable of moving a 203.3-mm (8-in.) diameter, 47-mm (1.85-in.) wide steel wheel, and a load of 705 ± 4.5 N (158 ± 1.0 lb) across the specimen at a rate of 52 ± 2 passes per minute.

Temperature control system – Capable of controlling temperature within ± 1.0 °C (1.8 °F) over the range of 25 to 70 °C (77 to 158°F) with circulating system.

Impression measurement system – An LVDT device capable of measuring the depth of the impression of the wheel to within 0.15 mm (0.006 in.).

Figure 7: A Hamburg Wheel-Track Testing Machine

Compaction equipment – Either a linear kneading compactor or a Superpave gyratory compactor.

Specimen mounting systems – Stainless steel tray suspended in the machine for either a slab specimen or a cylindrical specimen. High-density polyethylene molds are used to hold cylindrical specimens in place (Figure 9).

Balance – 12 kg capacity, accurate to 0.1 g.

Sample Preparation

Two test specimens are prepared as either slab specimens or cylinders, as well as either lab compacted or field-produced.

Preparation using Superpave gyratory cylindrical specimens

Prepare two cylindrical specimens according to AASHTO T312 for each Hamburg test specimen. Each specimen should have a 6 in. diameter and have a thickness of 38 to 100 mm (1.5 to 4 in.). After a minimum of 24 hr. after compaction, cut the specimens using a wet saw along a secant line (or chord) such that, when joined together in the molds, there is no space between the cut edges.

Preparation for slab specimens

Compact material into slab specimens using a Linear Kneading Compactor (or equivalent) to specifications of 320 mm (1.5 in.) long and 260 mm (10.25 in.) wide.

Determine the bulk specific gravity (T166), maximum specific gravity (T209), and air void content (T269) for each specimen. Laboratory-compacted specimen are recommended to target an air void content of 7.0 ± 1.0 percent, and field specimens are tested as obtained.

Procedure

Step 1

Mounting

Slab and large field core specimen mounting

Use plaster of paris, at a 1:1 ratio with water, to rigidly mount the slab specimens in the mounting trays. Allow the plaster at least one hour to set. A different mounting material may be used that is able to withstand 890 N (200 lb) of load without cracking. (Figure 8)

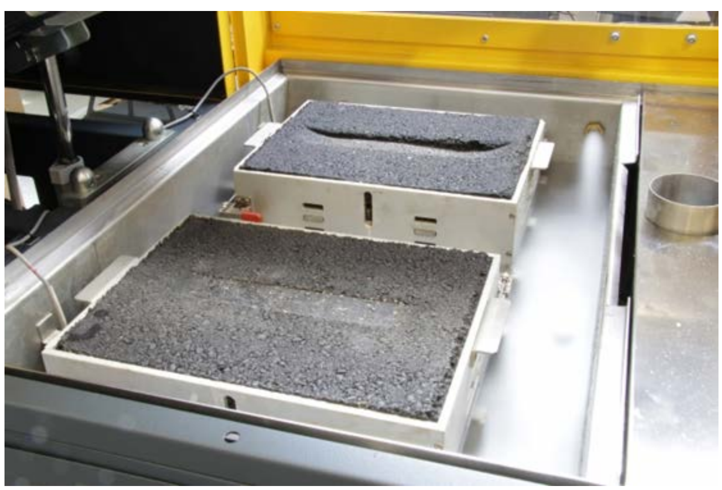


Figure 8: Laboratory Compacted Slab Specimens

Gyratory cylindrical and field core specimen mounting

Place the high density polyethylene molds in the mounting trays of the Hamburg machine, then place the cut specimens into the molds. Secure the molds into the mounting tray as shown in Figure 9.

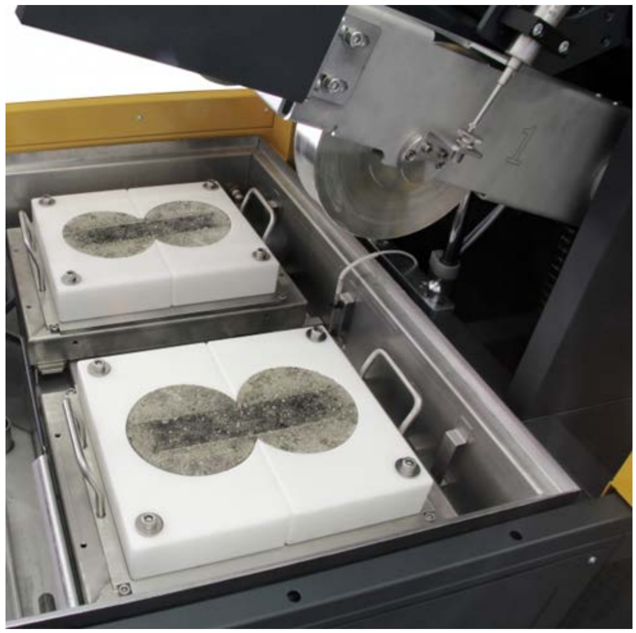


Figure 9: Gyratory Specimens Mounted in High-Density Polyethelyne Molds

Step 2

Secure the mounting trays with the test specimens into the Hamburg device.

Step 3

Enter the project information and testing parameters into the device's software including the test temperature and maximum allowable rut depth.

Note: Most devices will automatically open and close the valves to fill and drain the water bath. However, some older machines require this to be done manually.

Step 4

Set a start delay of 30 minutes to condition the specimens to the test temperature.

Step 5

Adjust the LVDTs for each specimen to the location specified by the manufacturer.

Step 6

Lower the wheels onto the edge of the test specimens so that a major of the weight is off the edge of the specimens.

Step 7

Start the test, which will automatically shut off when 20,000 passes have occurred or when the test has achieved the maximum rut depth.

Step 8

Raise the wheel and remove the specimens.

Calculations

Plot the rut depth versus number of passes for each test (Figure 10) and determine the Stripping Inflection Point (SIP):

$$SIP = \frac{Intercept\ (second\ portion - Intercept\ (first\ portion)}{Slope\ (first\ portion) - Slope\ (second\ portion)}$$

Failure rut depth is the specified maximum allowable rut depth for the test.

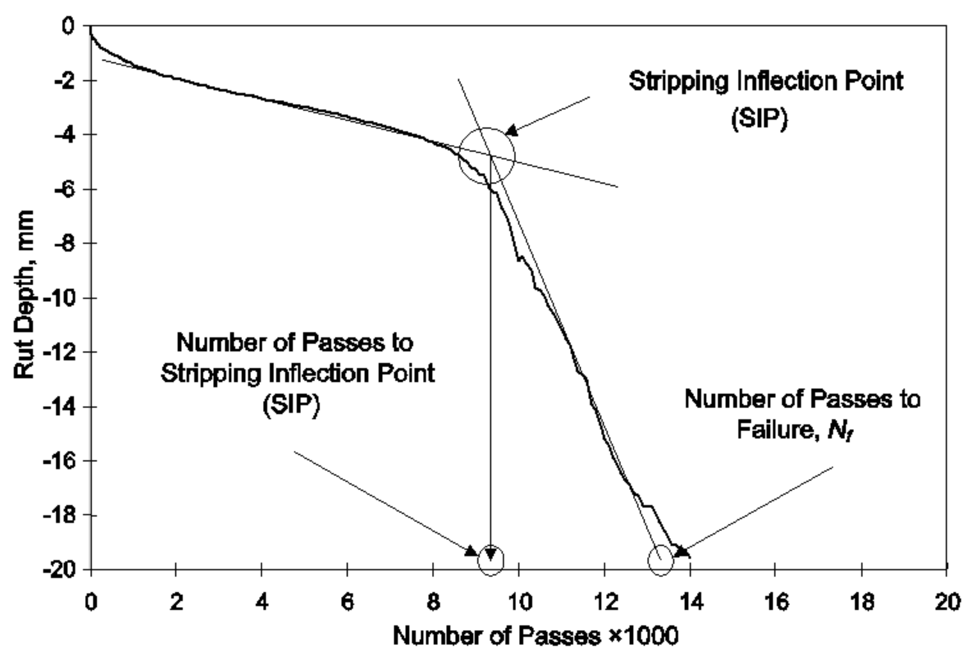


Figure 10: Hamburg Curve with Test Parameters

Reporting the Test Results

Report HMA Production (Field or Lab), Compaction method (slab or SGC cylindrical specimen), Number of passes at maximum impression, Maximum impression, Test temperature, Specimen(s) air voids, Type and amount of anti-stripping additive used, Creep slope, Strip slope, and Stripping inflection point.

AASHTO TP 79, Determining the Dynamic Modulus and Flow Numbers for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)

Background Information

The AMPT is a computer-controlled hydraulic testing machine capable of subjecting a compacted asphalt mixture specimen to cyclic loading over a range of temperatures and frequencies. The device evaluates asphalt mixture properties to assess potential performance. Transportation agencies can use the AMPT to develop inputs for the structural design of flexible pavements and to obtain information helpful in monitoring mixes and performing quality assurance. The current equipment and test methods have been developed to optimize both testing time and cost. The AMPT has also been known as the Simple Performance Tester (SPT) in earlier research work and references.

Significance and Use

The dynamic modulus is a performance-related property that can be used for mixture evaluation and for characterizing the stiffness of asphalt mixtures for mechanistic-empirical pavement design.

The flow number is a property related to the resistance of asphalt mixtures to permanent deformation. It can be used to evaluate and design asphalt mixtures with specific resistance to permanent deformation.

Related Tests and Specifications

- AASHTO PP 60, Preparation of Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor
- AASHTO T 342 - Determining Dynamic Modulus of Hot Mix Asphalt (HMA)

Timeline for Completion

Prep Time: 42 hours

Samples of aggregates are batched and placed in an oven at the mixing temperature overnight. Asphalt is placed in the oven at the mixing temperature for about 90 minutes before mixing. Asphalt mixture samples are mixed and compacted. The compacted specimens are bulked and then cut the following day. Before flow number testing, the specimens are conditioned at the test temperature in the environmental chamber for about 6 hours.

Time to Perform Procedure: 2 hours 47 minutes

Depending on the materials resistance and the test confinement, the test could take between a minimum of 30 minutes and a maximum of 2 hours and 47 minutes.

Calculations: 1 hour

TOTAL TIME: Approximately 43 hours

Apparatus

Specimen fabrication equipment – For fabricating test specimens in accordance with PP 60.

Dynamic modulus test system – Must meet the requirement of the equipment specification for the SPT System, Version 3.0.

Figure 11: LVDTs Mounted to a Dummy Specimen in a 120° Configuration

Conditioning chamber – An environmental chamber for conditioning the test specimens to the desired testing temperature. The chamber shall be capable of controlling the temperature of the specimen over the range from 4 to 70 °C with an accuracy of ± 0.5 °C.

TFE-fluorocarbon sheet – Thickness of 0.25 mm, to be used as a friction reducer between the specimen and the loading platens in the dynamic modulus test. See Annex A for further information on friction reducers.

Latex membranes – 100-mm in diameter by 0.3 mm thick, for use in confined tests and for manufacturing "greased double latex" friction reducers to be used between the specimen and the platens during testing.

Silicone grease – Dow Corning "stopcock grease" or equivalent, for manufacturing the double latex friction reducers.

Balance – Capable of determining mass to the nearest 0.01 g; to be used for massing silicone grease used for the double latex friction reducers.

Sample Preparation

Procedure A – Dynamic Modulus Test

Specimens shall be fabricated in accordance with PP 60, to a height of 150 mm and a diameter of 100 mm. A minimum of two specimens shall be prepared at the target air void content ± 0.5%. More specimens may be compacted depending on the desired accuracy of the results. Attach the gauge points to the specimen, ensuring that the gauge length is 70 ± 1 mm. Ensure that the top platen is free to rotate.

Procedure B – Flow Number Test

Specimens shall be fabricated in accordance with PP 60, to a height of 150 mm and a diameter of 100 mm. A minimum of three specimens shall be prepared at the target air void content ± 0.5%. More specimens may be compacted depending on the desired accuracy of the results. The top platen shall not be free to rotate.

Procedure – Procedure A - Dynamic Modulus Test – Unconfined

Step 1

Place the test specimen(s) in the environmental chamber with the “dummy” specimen. Monitor the temperature of the dummy to determine when testing may begin.

Step 2

Place the platens and friction reducers in the testing chamber. Turn on the AMPT, set the temperature to the target, and allow the chamber to reach equilibrium for a minimum of one hour.

Step 3

Once the dummy indicates that the target temperature has been reached, remove the specimen from the environmental chamber, and place the specimen in the heated platens. Friction reducers must be used between the specimen and the platens.

Step 4

Install the specimen-mounted deformation-measuring system on the gauge points per the manufacturer’s instructions. Close the testing chamber and allow the temperature to return to the testing temperature.

Step 5

Steps 3 and 4 must be completed in under 5 minutes.

Step 6
Enter required information in to the dynamic modulus software and follow the prompts to begin testing.

Step 7
After the completion of testing, remove the specimen from the testing chamber, and test any remaining specimens in a similar fashion.

Procedure – Procedure A - Dynamic Modulus Test – Confined

Step 1
Assemble each specimen to be tested with the platens and membrane as follows: place the bottom friction reducer and the specimen on the bottom platen. Stretch the membrane over the specimen and bottom loading platen. Install the lower O-ring.

Step 2
Place the top friction reducer and top platen on top of the specimen and stretch the membrane over the top platen. Install the top O-ring.

Step 3
Ensure that friction reducers are equipped with vent holes. These holes ensure the specimen remains at atmospheric pressure.

Step 4
Repeat steps 1–3 for the dummy specimen.

Step 5
Place the test specimen(s) in the environmental chamber with the dummy specimen. Monitor the temperature of the dummy to determine when testing may begin.

Step 6
Place the platens and friction reducers in the testing chamber. Turn on the AMPT, set the temperature to the target, and allow the chamber to reach equilibrium for a minimum of 1 hour.

Step 7
Once the dummy indicates that the target temperature has been reached, remove the specimen from the environmental chamber, and place the specimen in the heated platens. Friction reducers must be used between the specimen and the platens.

Step 8
Install the specimen-mounted deformation-measuring system on the gauge points per the manufacturer's instructions. Close the testing chamber and allow the temperature to return to the testing temperature.

Step 9
Steps 7 and 8 must be completed in under 5 minutes.

Step 10
Enter required information in to the dynamic modulus software and follow the prompts to begin testing.

Step 11
After the completion of testing, remove the specimen from the testing chamber, and test any remaining specimens in a similar fashion.

Procedure – Procedure B - Flow Number Test – Unconfined

Step 1
Place the test specimen(s) in the environmental chamber with the "dummy" specimen. Monitor the temperature of the dummy to determine when testing may begin.

Step 2
Place the platens and friction reducers in the testing chamber. Turn on the AMPT, set the temperature to the target, and allow the chamber to reach equilibrium for a minimum of one hour.

Step 3
Once the dummy indicates that the target temperature has been reached, remove the specimen from the environmental chamber, and place the specimen in the heated platens. Friction reducers must be used between the specimen and the platens.

Step 4
Close the testing chamber and allow the temperature to return to the testing temperature. Ensure that the top loading platen is fixed in place and not allowed to rotate during testing.

Step 5
Steps 3 and 4 must be completed in under 5 minutes.

Step 6
Enter required information in to the flow number software and follow the prompts to begin testing.

Step 7
After the completion of testing, remove the specimen from the testing chamber, and test any remaining specimens in a similar fashion.

Procedure – Procedure B – Flow Number – Unconfined

Step 1
Assemble each specimen to be tested with the platens and membrane as follows: place the bottom friction reducer and the specimen on the bottom platen. Stretch the membrane over the specimen and bottom loading platen. Install the lower O-ring.

Step 2
Place the top friction reducer and top platen on top of the specimen and stretch the membrane over the top platen. Install the top O-ring.

Step 3
Ensure that the friction reducers are equipped with vent holes. These holes ensure the specimen remains at atmospheric pressure.

Step 4
Repeat steps 1–3 for the dummy specimen.

Step 5
Place the test specimen(s) in the environmental chamber with the “dummy” specimen. Monitor the temperature of the dummy to determine when testing may begin.

Step 6
Place the platens and friction reducers in the testing chamber. Turn on the AMPT, set the temperature to the target, and allow the chamber to reach equilibrium for a minimum of 1 hour.

Step 7
Once the dummy indicates that the target temperature has been reached, remove the specimen from the environmental chamber, and place the specimen in the heated platens. Friction reducers must be used between the specimen and the platens.

Step 8
Close the testing chamber and allow the temperature to return to the testing temperature. Ensure that the top loading platen is fixed in place and not allowed to rotate during testing.

Step 9
Steps 7 and 8 must be completed in under 5 minutes.

Step 10
Enter required information in to the flow number software and follow the prompts to begin testing.

Step 11
After the completion of testing, remove the specimen from the testing chamber, and test any remaining specimens in a similar fashion.

Calculations

Procedure A – Dynamic Modulus Test
The calculation of dynamic modulus (E* in MPa), phase angle, and the data quality indicators is performed automatically by the AMPT software.

Procedure B – Flow Number Test
The calculation of the permanent strain for each load cycle and the flow number (F_n) for individual specimens is performed automatically by the AMPT software.

Compute the average and standard deviation of the flow numbers for the replicate specimens tested. Compute the average and standard deviation of the permanent strain at the load cycles of interest.

Reporting the Test Results

Procedure A – Dynamic Modulus Test
For each test specimen, report the following:

- Test temperature
- Test frequency
- Confining stress level
- Dynamic modulus, E* (to the nearest MPa)
- Phase angle
- Data quality statistics

Attach the AMPT dynamic modulus test summary report for each specimen tested.

Procedure B – Flow Number Test
Report the following:

- Test temperature
- Average applied deviatory stress
- Average applied confining stress

- Average and standard deviation of the flow numbers for the specimens tested
- Average standard deviation of the permanent strain at the load cycles of interest

Attach the AMPT flow number test summary report for each specimen tested

Related Procedure – AASHTO T 342, Determining Dynamic Modulus of Hot Mix Asphalt

Comparison

The sample preparation and setup is essentially the same as the AASHTO TP 79 unconfined test. An AMPT device is normally used for testing. The specific AASHTO T 342 is as follows:

Procedure

Step 1
The test series for the development of master curves for use in pavement response and performance analysis shall be conducted at -10, 4.4, 21.1, 37.8, and 54 °C (14, 40, 70, 100, and 130 °F) at loading frequencies of 0.1, 0.5, 1.0, 5, 10, and 25 Hz at each temperature.

Step 2
Apply a contact load (P_{min}) equal to 5% of the dynamic load that will be applied to the specimen. It is acceptable to increase the applied contact stress to 20 kPa to improve machine control effectiveness by applying a load that will maintain positive contact with the specimen but will not damage the specimen.

Step 3
At the beginning of testing, precondition the specimen with 200 cycles at 25 Hz at the stress level corresponding to Table 5 in T 342.

Step 4
Apply sinusoidal (haversine) loading ($P_{dynamic}$) to the specimen in a cyclic manner. The dynamic load should be adjusted to obtain axial strains between 50 and 150 microstrain. Table 5 in T 342 gives typical dynamic stress levels and Table 6 gives the number of cycles for each test sequence.

Step 5
Test each of the 30 combinations of temperature and frequency of loading starting with the lowest temperature and proceeding to the highest and with the highest frequency of loading and proceeding to the lowest.

Step 6

A typical rest period between each frequency run is 2 minutes. This rest period shall not exceed 30 minutes for any two frequency runs.

Calculations

The data produced from each dynamic modulus test at frequency ω0 are stored in the form of several arrays, one for time [ti], one for stress [σi], and one for each of the j = 1, 2, 3,…m strain transducers used [∈j]. The number of i = 1, 2, 3…n points in each array will be equal and will depend upon the number of data points collected per loading cycle and on the total number of cycles for which data has been collected. It is recommended that 50 points per cycle and 5 cycles be used for a total of 250 data points. The software for this test will conduct the calculations for Sections 12.4–12.6 of T 342, ultimately giving the overall phase angle θ(ω), in degrees, and the complex modulus, |E*(ω)|, kPa ,at the selected frequency, ω.

Reporting the Test Results

The following is reported for each specimen, at each of the temperature and frequency combinations: test temperature, test frequency, dynamic modulus, average phase angle between applied stress and measured strain, average strain magnitude, stress magnitude, standard error of the applied stress, average standard error of the measured, uniformity coefficient for the strain measurements, and uniformity coefficient for the phase angle measurements.

Mixture	Air Voids	VMA	VFA
PG 58-28	5.1	14.5	64.8

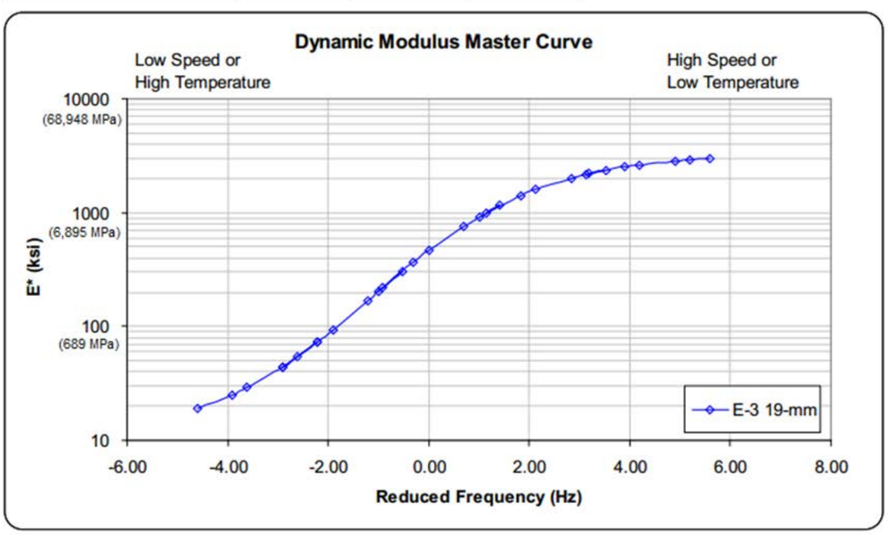


Figure 12: Example master curve for dynamic modulus

Appendix A: Lab Materials

HMEC Module F Performance Testing

Wednesday, March 2, 2016

Please review the next page for your grouping and team assignments.

Times	Group A	Group B	Group C	Group D
TBD	**Prep Session**	**Prep Session**	**Prep Session**	**Prep Session**
TBD	**Station 1**	**Station 2**	**Station 3**	**Station 4**
TBD	**Station 2**	**Station 3**	**Station 4**	**Station 1**
TBD	**Station 3**	**Station 4**	**Station 1**	**Station 2**
TBD	**Station 4**	**Station 1**	**Station 2**	**Station 3**
TBD	**Debrief Session**	**Debrief Session**	**Debrief Session**	**Debrief Session**

Station 1
AASHTO T 321 Determining the Fatigue Life of Compacted Hot Mix Asphalt (HMA) Subjected to Repeated Flexural Bending

Station 2
AASHTO T 322 Determining the Creep Compliance and Strength of Hot Mix Asphalt (HMA) Using the Indirect Tensile Test Device

Station 3
AASHTO T 324 Hamburg Wheel-Track Testing of Compacted Hot-Mix Asphalt (HMA)

Station 4
AASHTO TP 79 Determining the Dynamic Modulus and Flow Number for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)

Station Locations
Station 1 will be performed in the HMEC Classroom (Upstairs)

Station 2 will be performed in the AMRL Conference Room

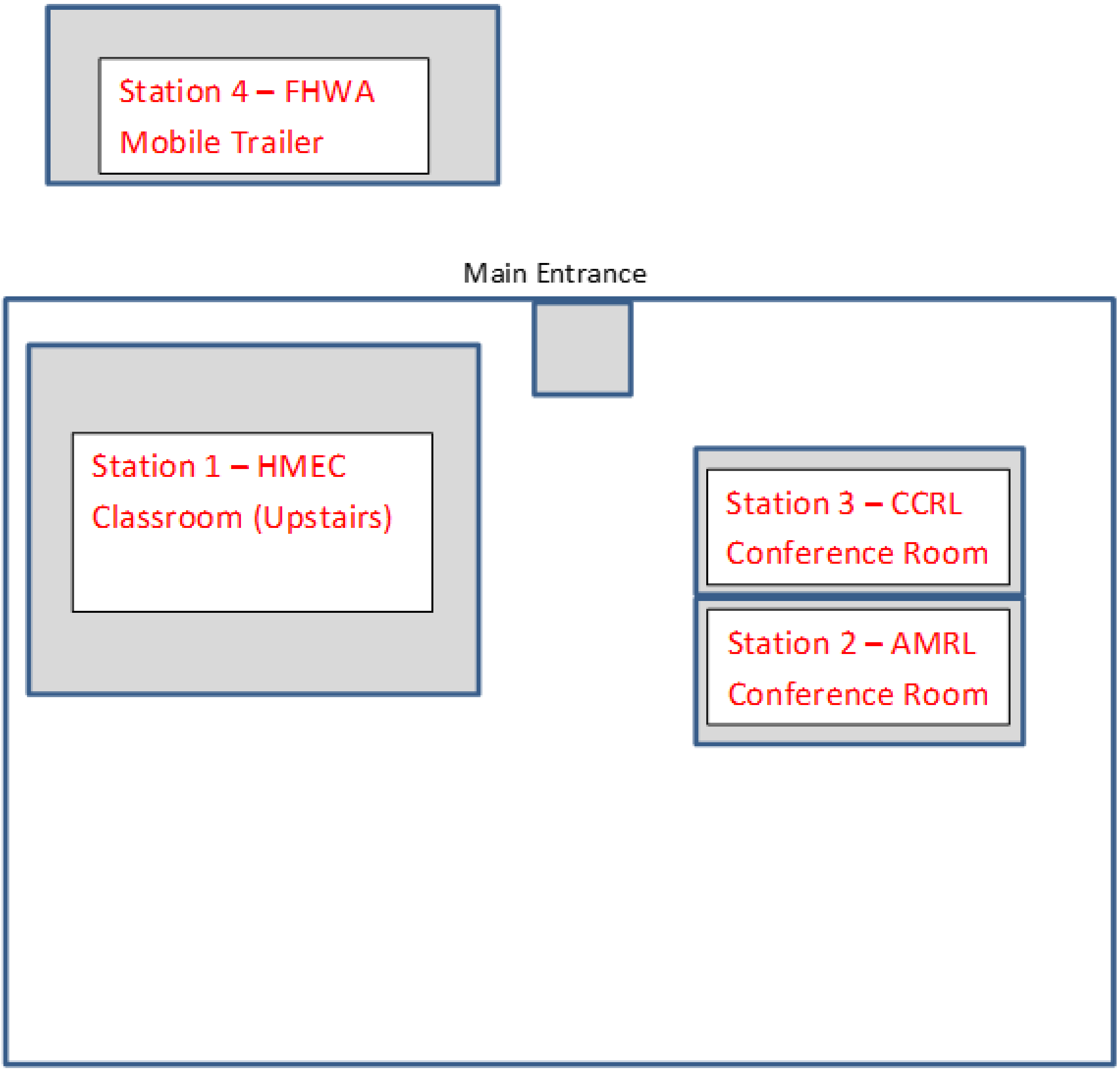
Station 3 will be performed in the CCRL Conference Room

Station 4 will be performed in the FHWA Mobile Laboratory

Team Assignments

To Be Determined

AMRL Laboratory Layout for Module F (Performance Tests)



Appendix B: Lab Presentations

AASHTO T 321

Slide 1

Slide 2

Lesson Introduction

By the end of this lesson, you will be able to:

- Understand the concept of fatigue cracking.
- Recognize the testing equipment and procedures needed to determine the fatigue of HMA pavements using the Repeated Flexural Bending Test (AASHTO T321).
- Explain how the Repeated Flexural Bending test is performed in the laboratory.
- Understand the purpose and use of the Flexural Fatigue Bending test results.

This lesson will take approximately 25 minutes to complete.

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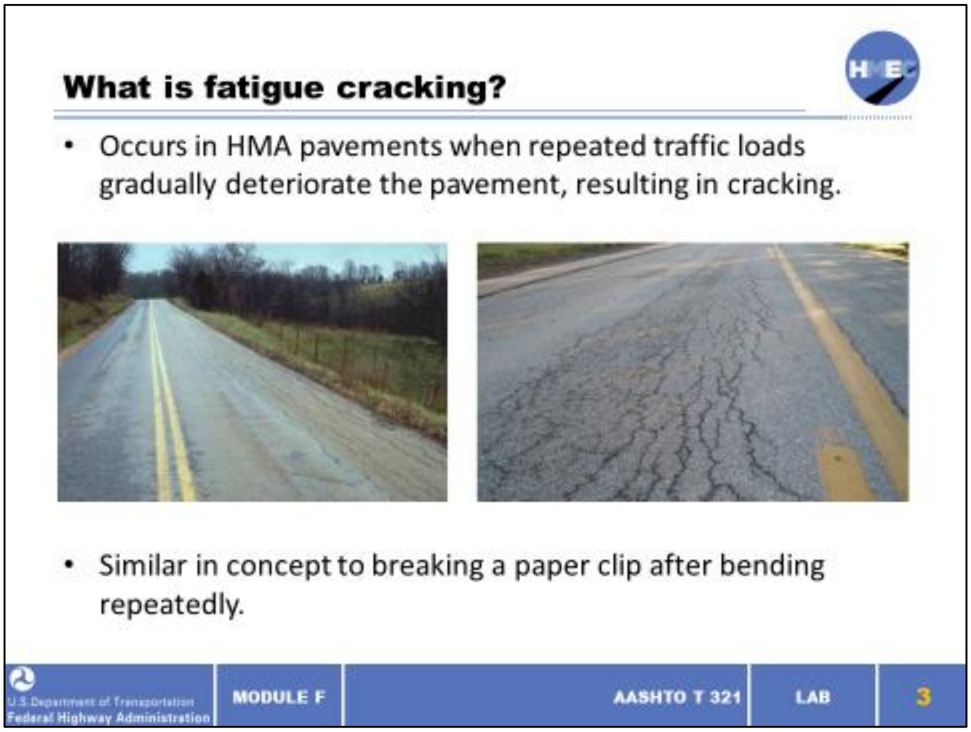
Slide 3


What is fatigue cracking?
• Occurs in HMA pavements when repeated traffic loads gradually deteriorate the pavement, resulting in cracking.
• Similar in concept to breaking a paper clip after bending repeatedly.
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LAB
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Slide 4

What is fatigue cracking?

- A classic fatigue crack usually begins at the bottom of the HMA pavement layer, eventually working toward the surface.
- Severe cracking is sometimes referred to as "alligatoring" as it can resemble the skin of an alligator.

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Slide 5

What is fatigue cracking?

- The severity of the cracking is proportional to the strain at the bottom layer of the HMA.
- Thicker pavements will have less strain at the bottom of the pavement.
- Fatigue cracking is the primary issue of concern in pavements subject to repeated loading at intermediate temperature ranges [10 to 30°C (50 to 86°F)] .
- At higher in-service temperatures [35°C (95°F)] , rutting is a primary concern, and at lower temperatures [5°C (41°F)] , thermal cracking is a primary concern.

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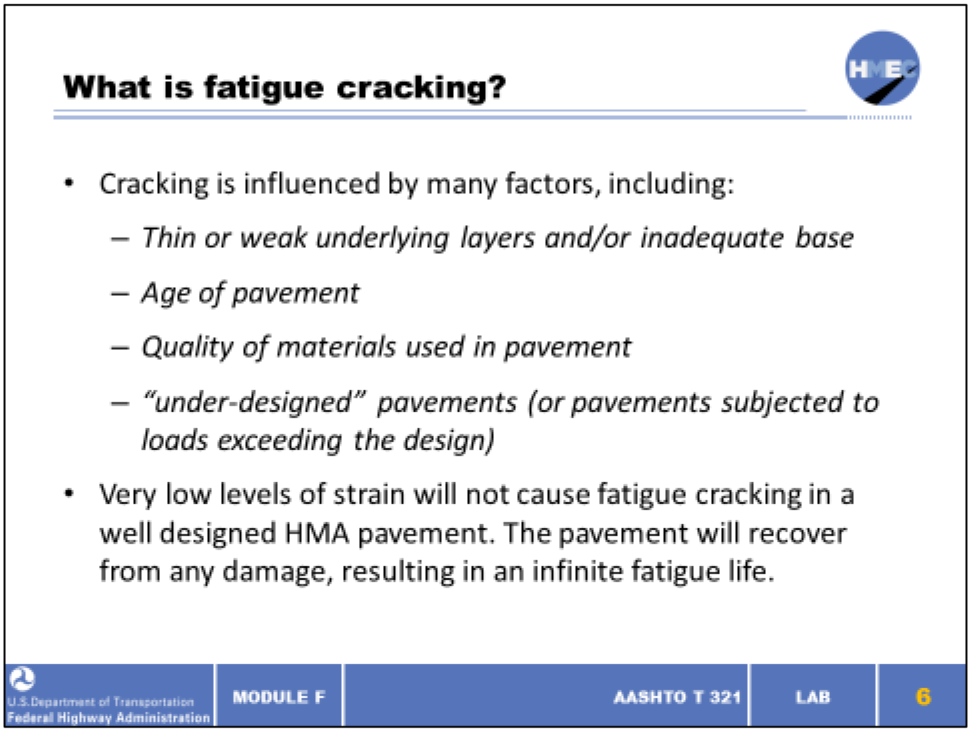
What is fatigue cracking?
• Cracking is influenced by many factors, including:
– Thin or weak underlying layers and/or inadequate base
– Age of pavement
– Quality of materials used in pavement
– "under-designed" pavements (or pavements subjected to loads exceeding the design)
• Very low levels of strain will not cause fatigue cracking in a well designed HMA pavement. The pavement will recover from any damage, resulting in an infinite fatigue life.
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Repeated Flexural Bending Test (AASHTO T321)

History:

- In the late 60's and early 70's, researchers began working to understand fatigue cracking and to predict fatigue performance of asphalt pavement.
- Since then, the beam fatigue test has been used extensively to simulate field conditions in the laboratory.
- Evaluation of fatigue cracking is incorporated in the Mechanistic Empirical Pavement Design Guide (MPEDG).

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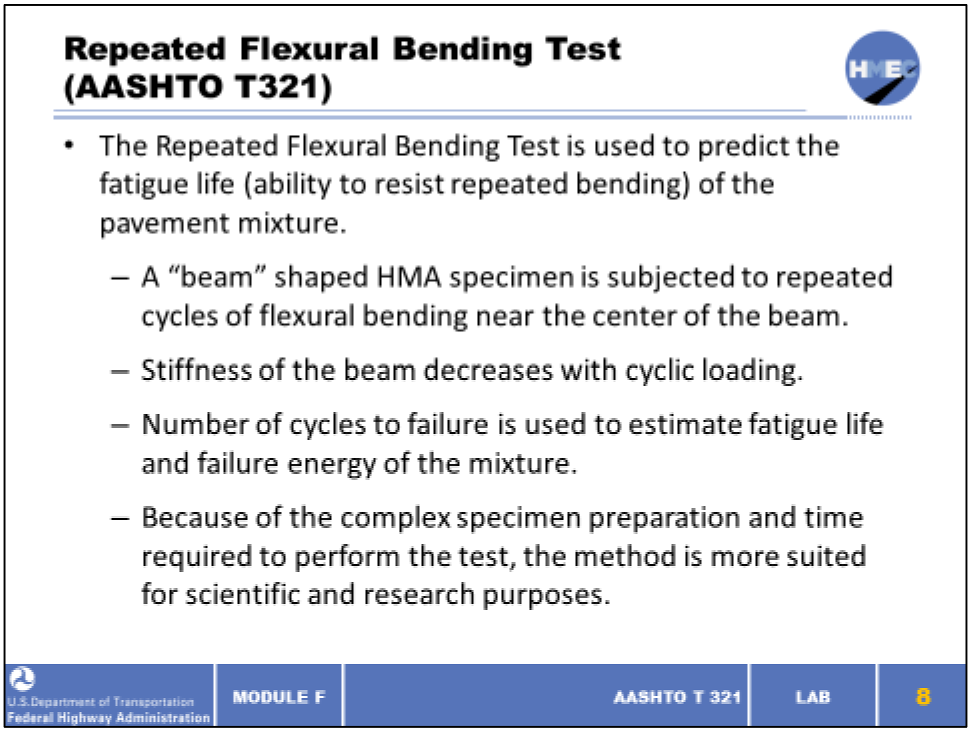
Repeated Flexural Bending Test (AASHTO T321)
HMEC
• The Repeated Flexural Bending Test is used to predict the fatigue life (ability to resist repeated bending) of the pavement mixture.
– A "beam" shaped HMA specimen is subjected to repeated cycles of flexural bending near the center of the beam.
– Stiffness of the beam decreases with cyclic loading.
– Number of cycles to failure is used to estimate fatigue life and failure energy of the mixture.
– Because of the complex specimen preparation and time required to perform the test, the method is more suited for scientific and research purposes.
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Apparatus

- Loading Device:
  - provides repeated sinusoidal loading at a frequency of 5 to 10 Hz.
  - subjects the specimen to four point bending.
  - forces specimen to original position after each loading pulse.

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Apparatus – Loading Device
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Apparatus – Loading Device
• Side View
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Apparatus – Loading Device
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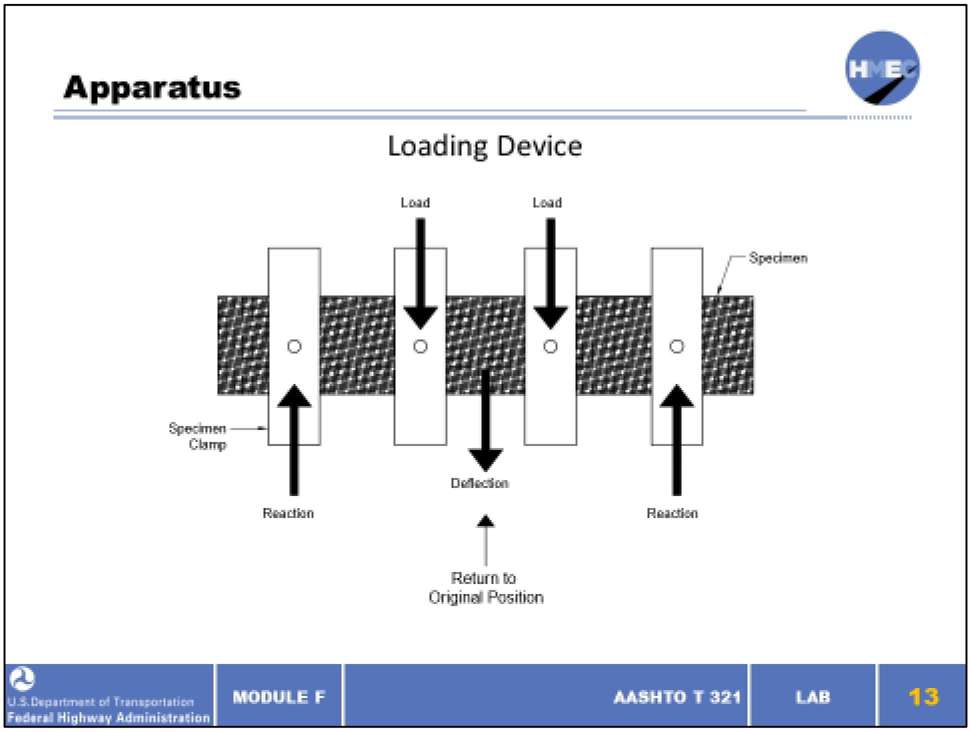
Apparatus
HMEC
Loading Device
Load
Load
Specimen
Specimen Clamp
Reaction
Deflection
Reaction
Return to Original Position
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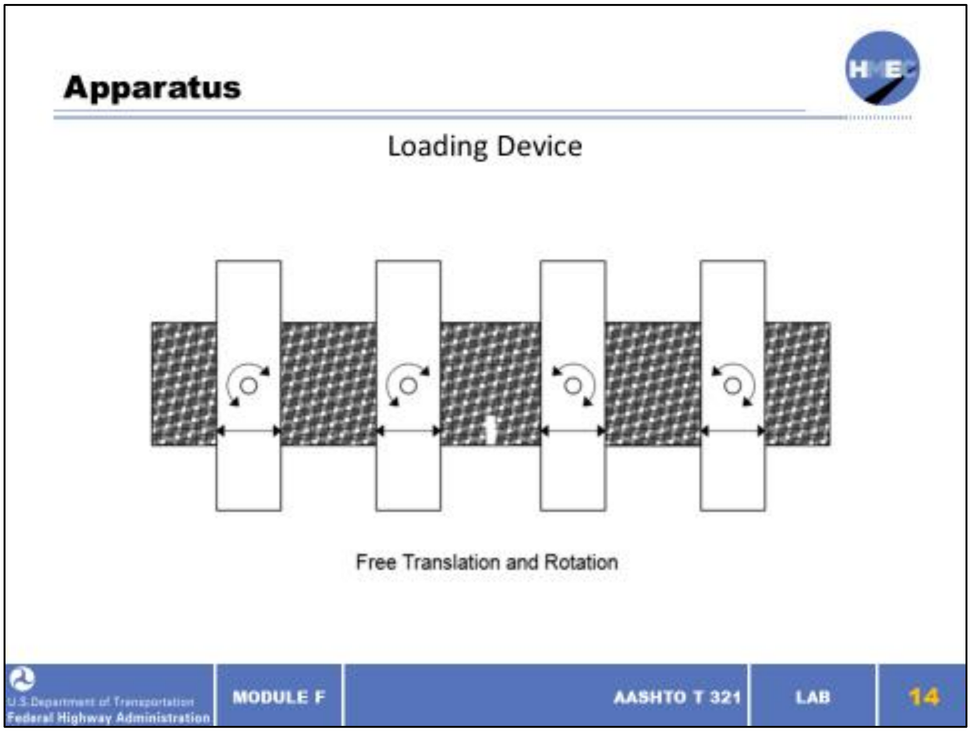
Apparatus
Loading Device
Free Translation and Rotation
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Slide 15

Apparatus

- Environmental chamber (optional)

- Control and Data acquisition system

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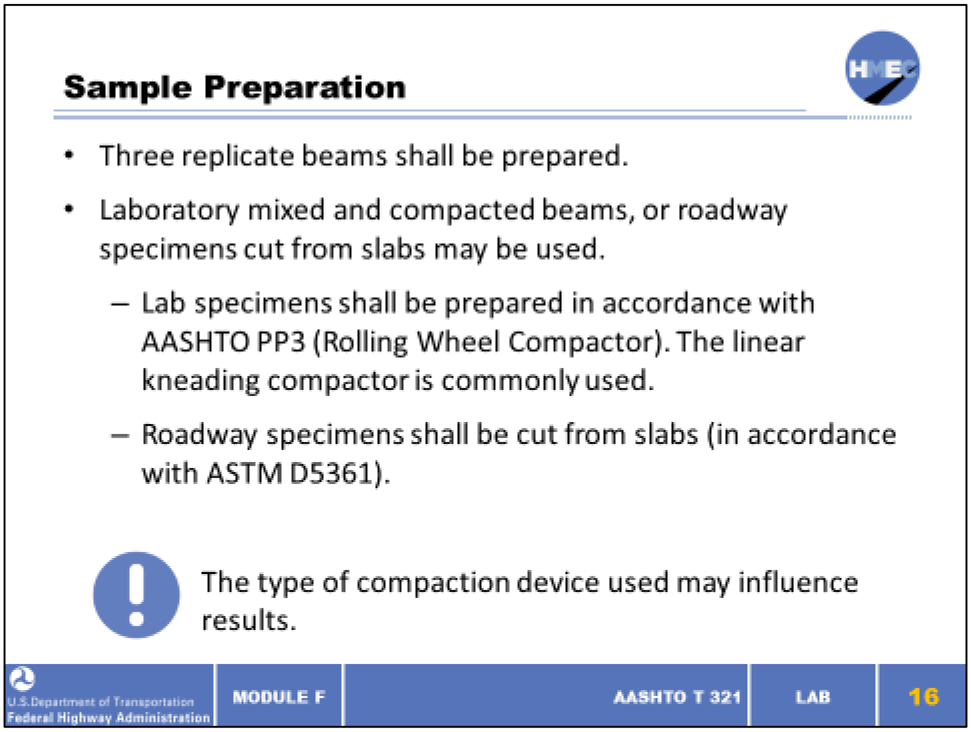
Sample Preparation
• Three replicate beams shall be prepared.
• Laboratory mixed and compacted beams, or roadway specimens cut from slabs may be used.
– Lab specimens shall be prepared in accordance with AASHTO PP3 (Rolling Wheel Compactor). The linear kneading compactor is commonly used.
– Roadway specimens shall be cut from slabs (in accordance with ASTM D5361).
The type of compaction device used may influence results.
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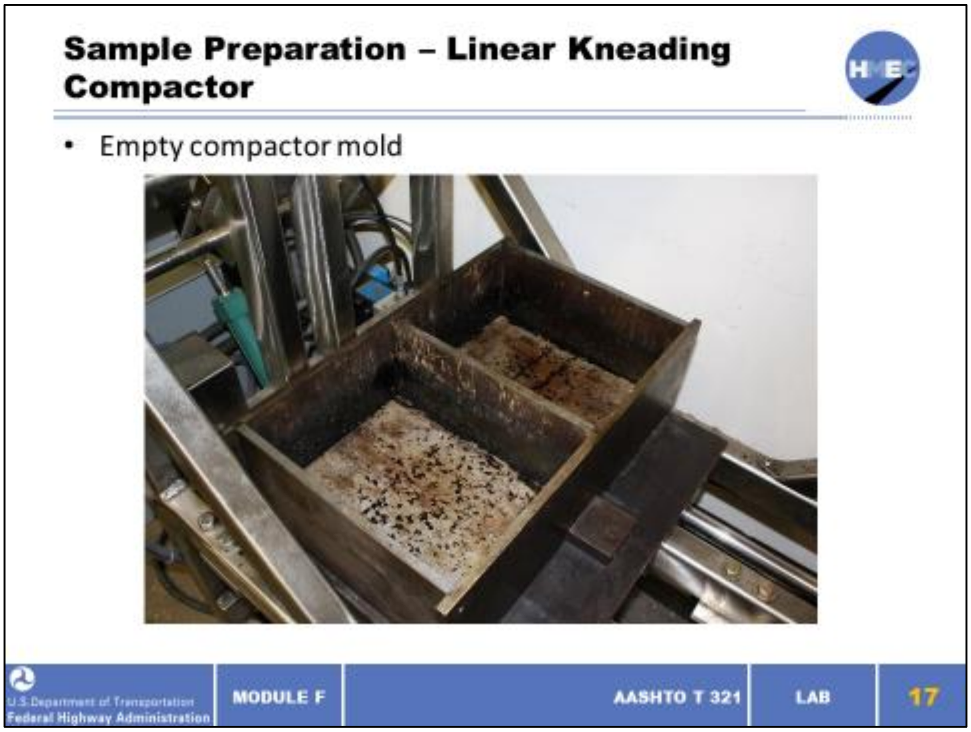
Sample Preparation – Linear Kneading Compactor
• Empty compactor mold
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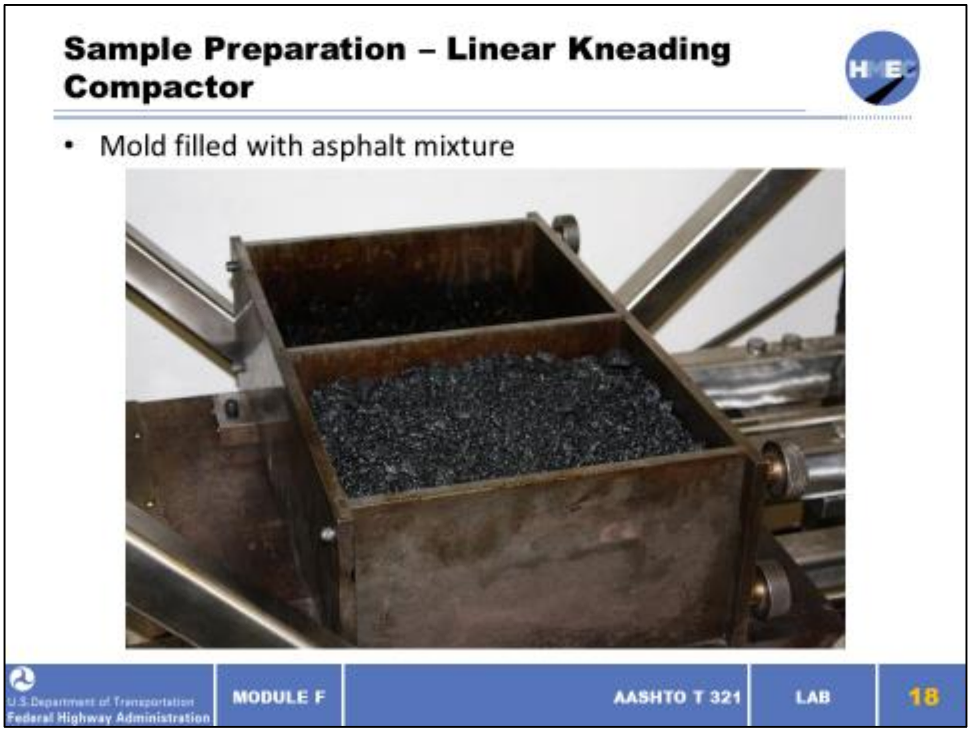
Sample Preparation – Linear Kneading Compactor
• Mold filled with asphalt mixture
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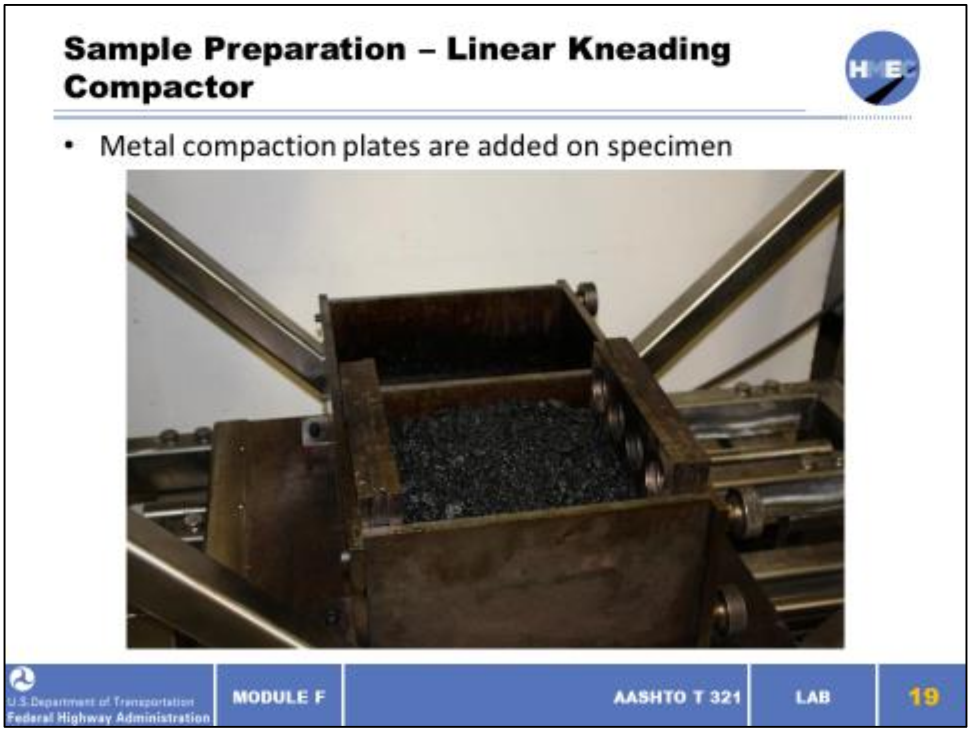
Sample Preparation – Linear Kneading Compactor
Metal compaction plates are added on specimen
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Sample Preparation – Linear Kneading Compactor
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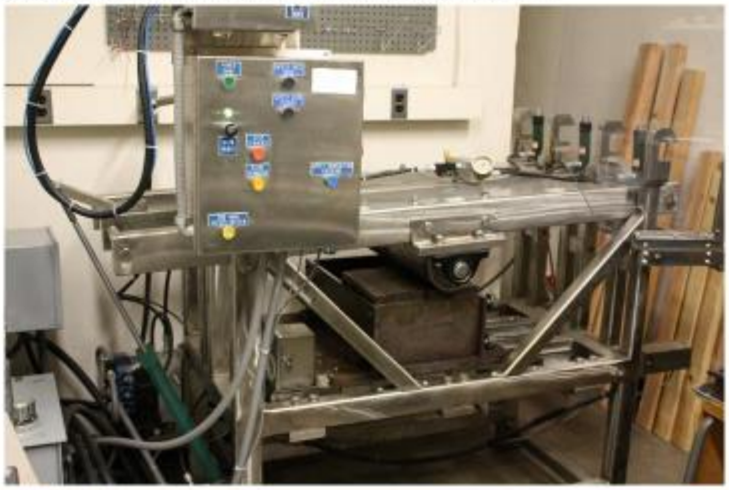
Sample Preparation – Linear Kneading Compactor

- Mold assembly is placed into the compactor



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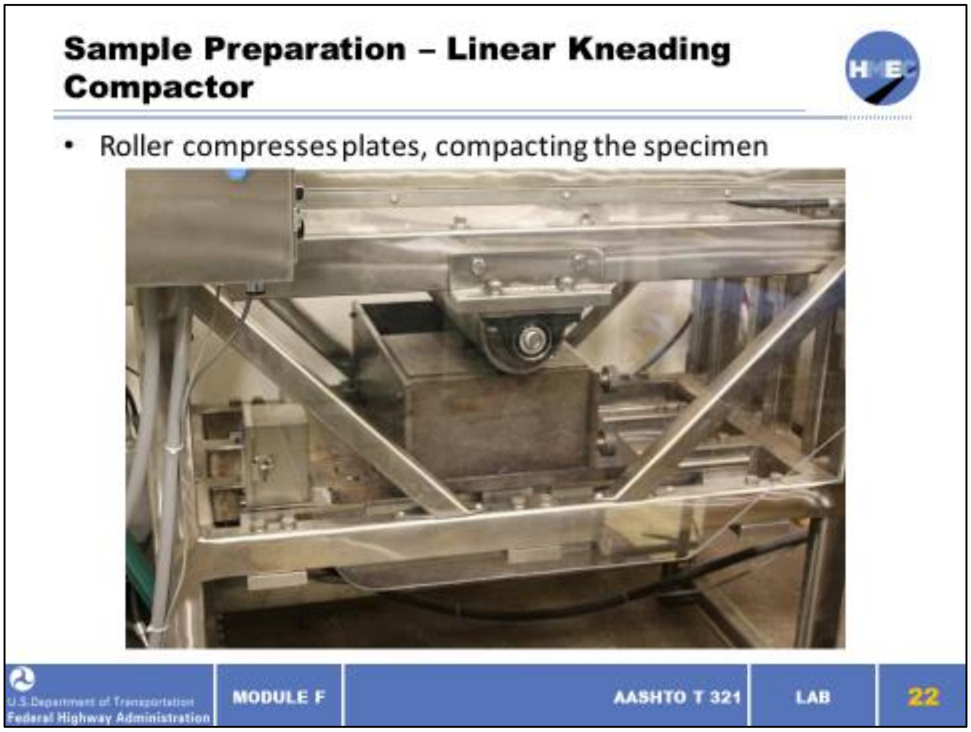
Sample Preparation – Linear Kneading Compactor
• Roller compresses plates, compacting the specimen
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Sample Preparation – Linear Kneading Compactor
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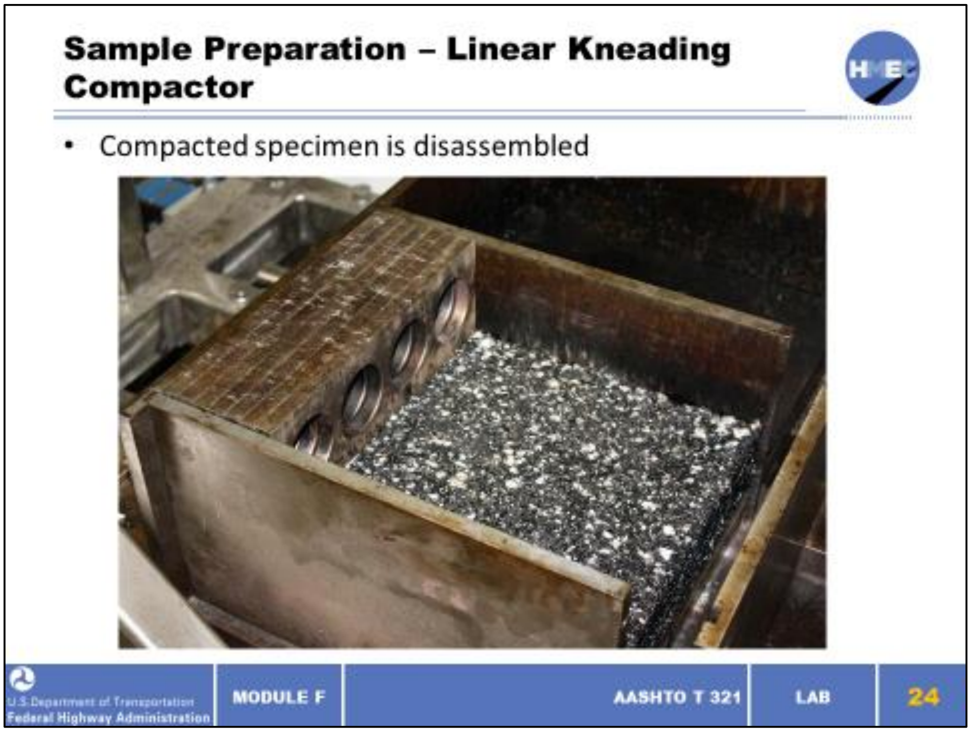
Sample Preparation – Linear Kneading Compactor
• Compacted specimen is disassembled
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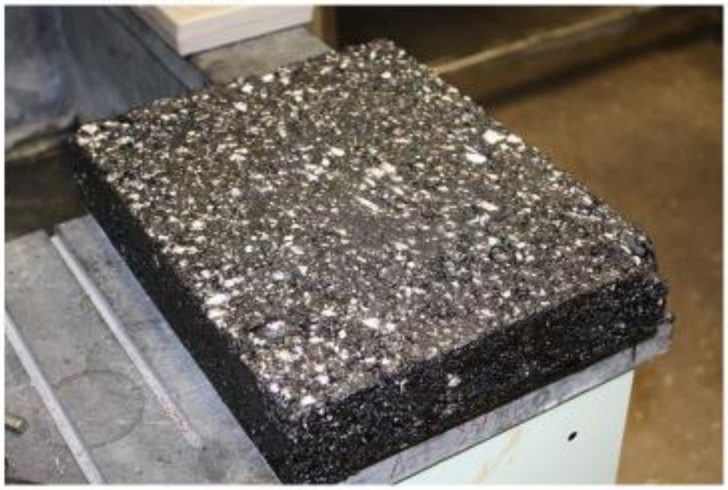
Sample Preparation – Linear Kneading Compactor

- Final compacted slab



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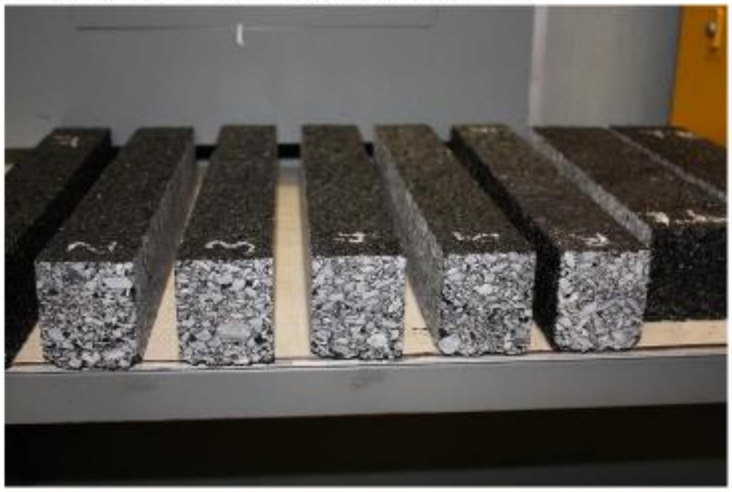
Sample Preparation – Linear Kneading Compactor

- Slab is then cut into individual test beams



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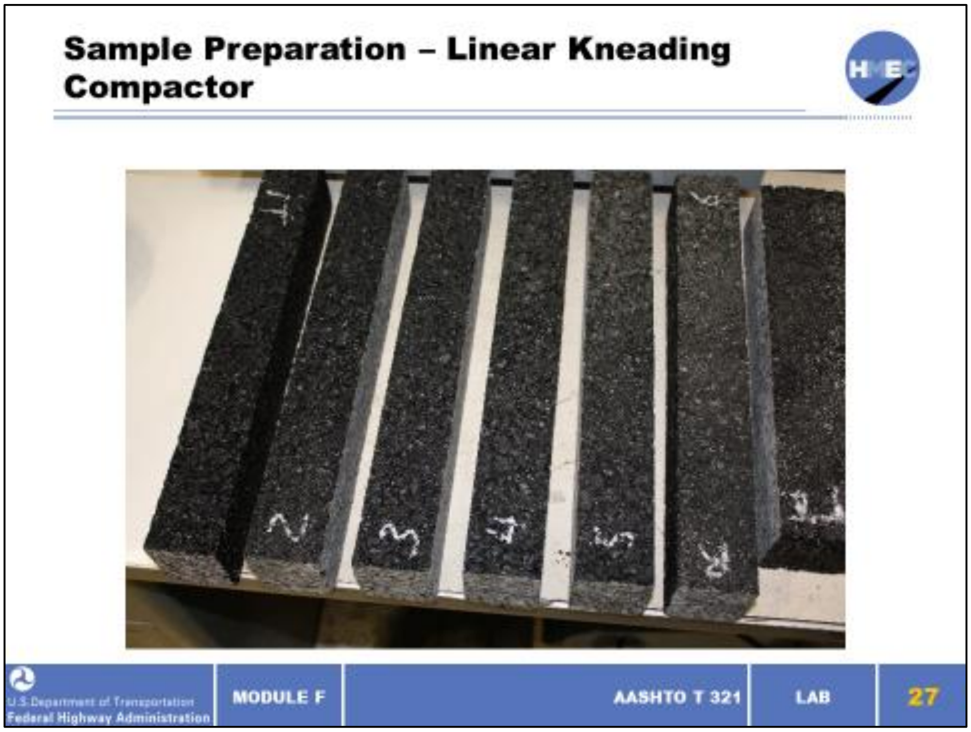
Sample Preparation – Linear Kneading Compactor
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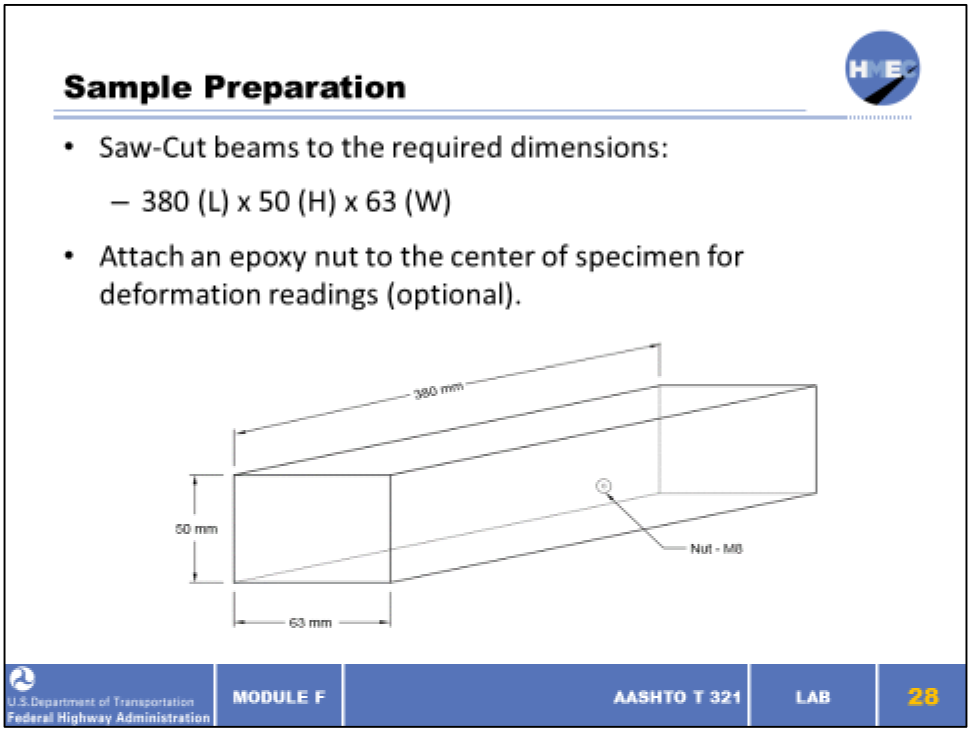
Sample Preparation
• Saw-Cut beams to the required dimensions:
– 380 (L) x 50 (H) x 63 (W)
• Attach an epoxy nut to the center of specimen for deformation readings (optional).
380 mm
50 mm
63 mm
Nut - M8
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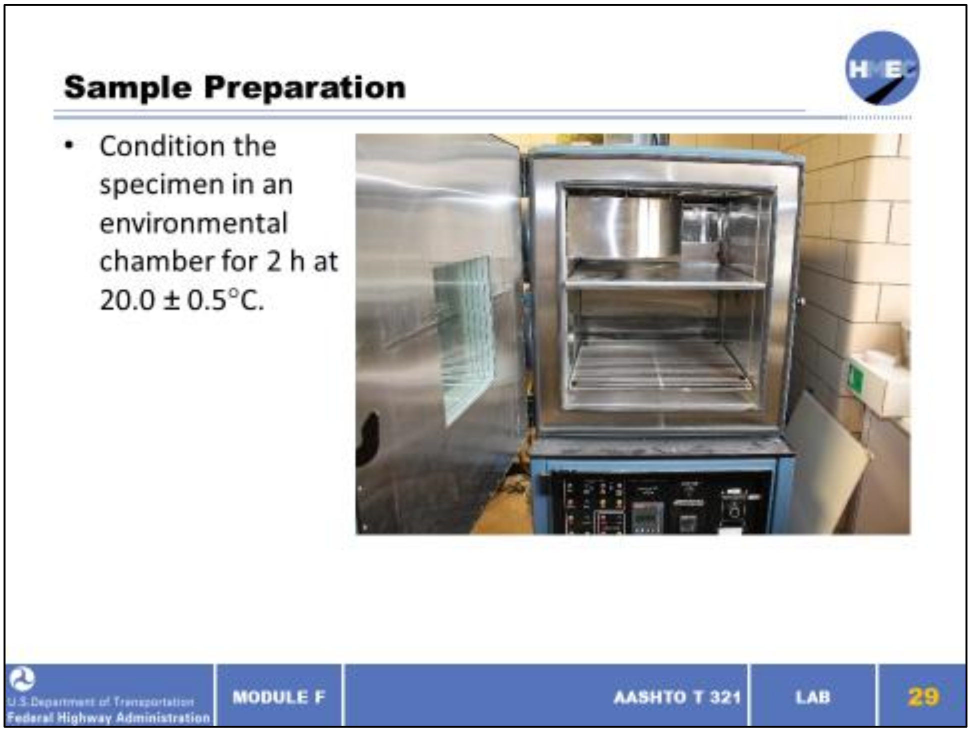
Sample Preparation
• Condition the specimen in an environmental chamber for 2 h at 20.0 ± 0.5°C.
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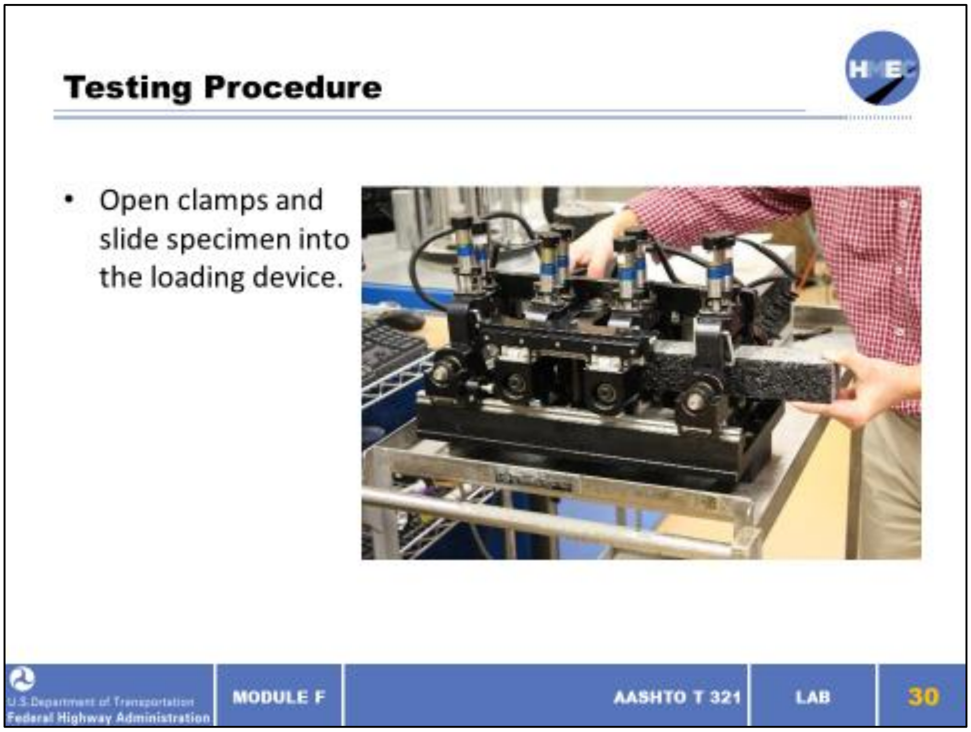
Testing Procedure
• Open clamps and slide specimen into the loading device.
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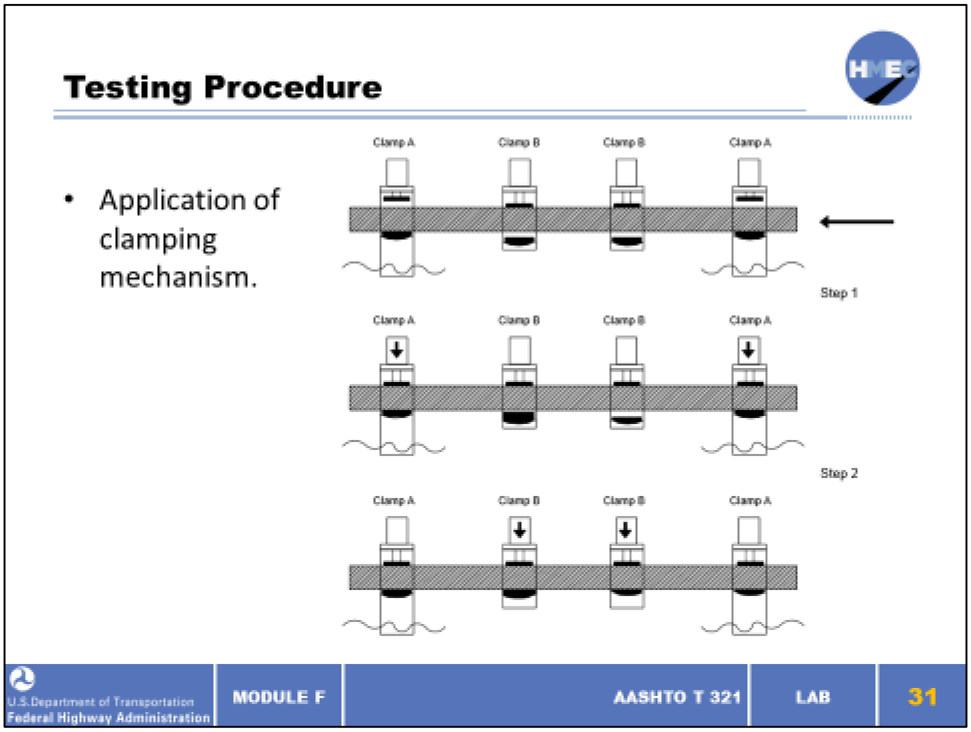
Testing Procedure
• Application of clamping mechanism.
Clamp A
Clamp B
Clamp B
Clamp A
Step 1
Step 2
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Testing Procedure
Close-up of Clamping Mechanism
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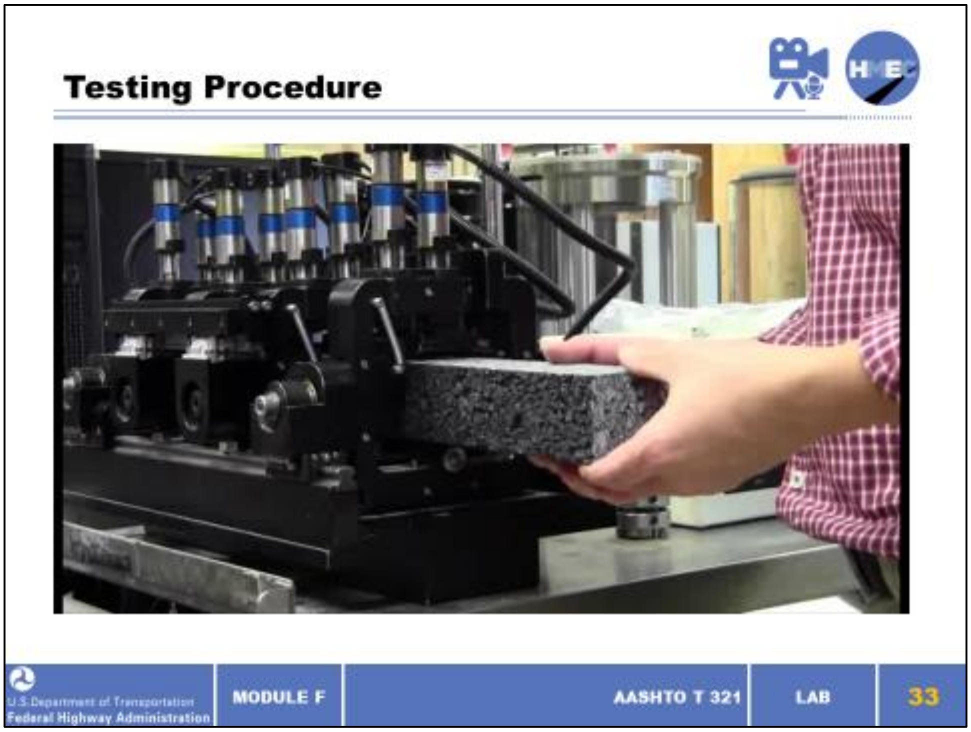
Testing Procedure
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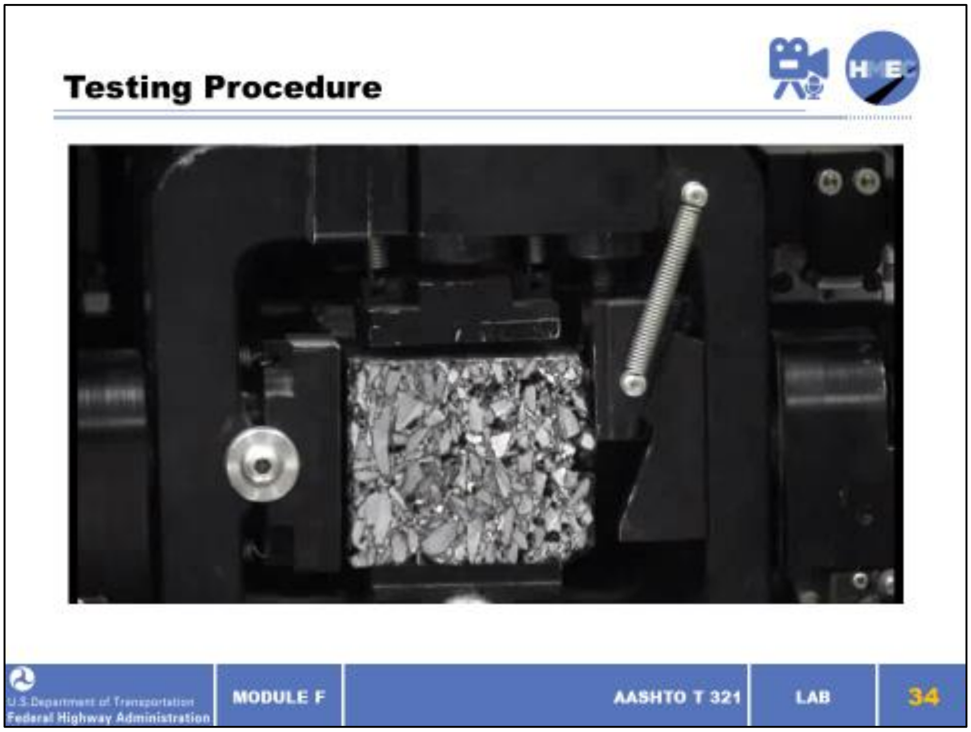
Testing Procedure
U.S. Department of Transportation
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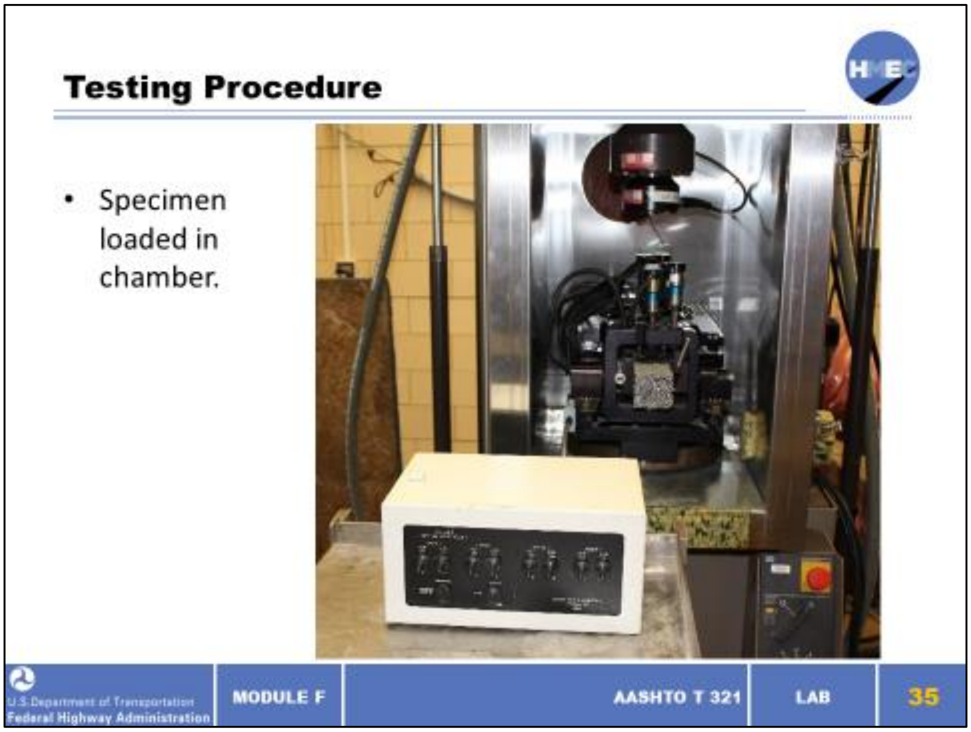
Testing Procedure
• Specimen loaded in chamber.
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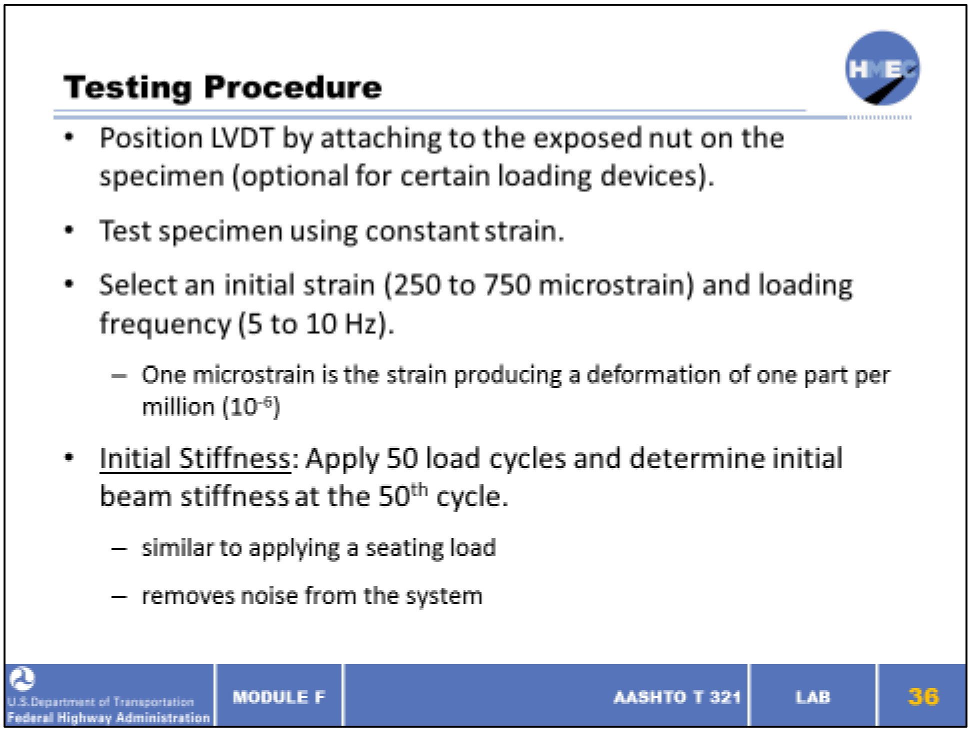
Testing Procedure
Position LVDT by attaching to the exposed nut on the specimen (optional for certain loading devices).
Test specimen using constant strain.
Select an initial strain (250 to 750 microstrain) and loading frequency (5 to 10 Hz).
One microstrain is the strain producing a deformation of one part per million (10-6)
Initial Stiffness: Apply 50 load cycles and determine initial beam stiffness at the 50th cycle.
similar to applying a seating load
removes noise from the system
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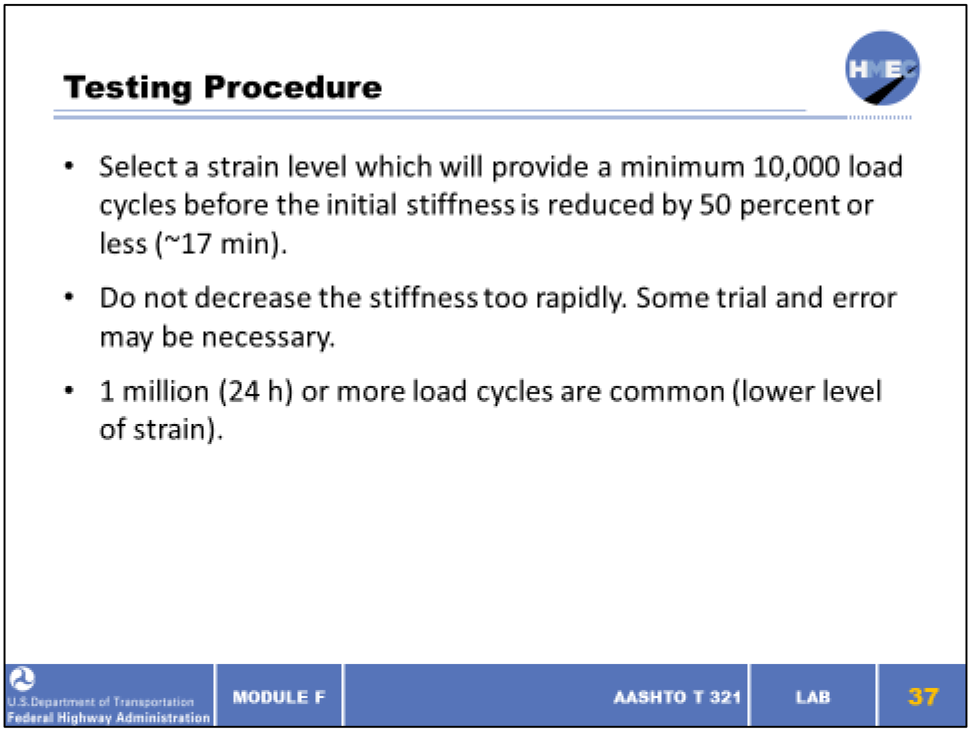
Testing Procedure
HMEC
• Select a strain level which will provide a minimum 10,000 load cycles before the initial stiffness is reduced by 50 percent or less (~17 min).
• Do not decrease the stiffness too rapidly. Some trial and error may be necessary.
• 1 million (24 h) or more load cycles are common (lower level of strain).
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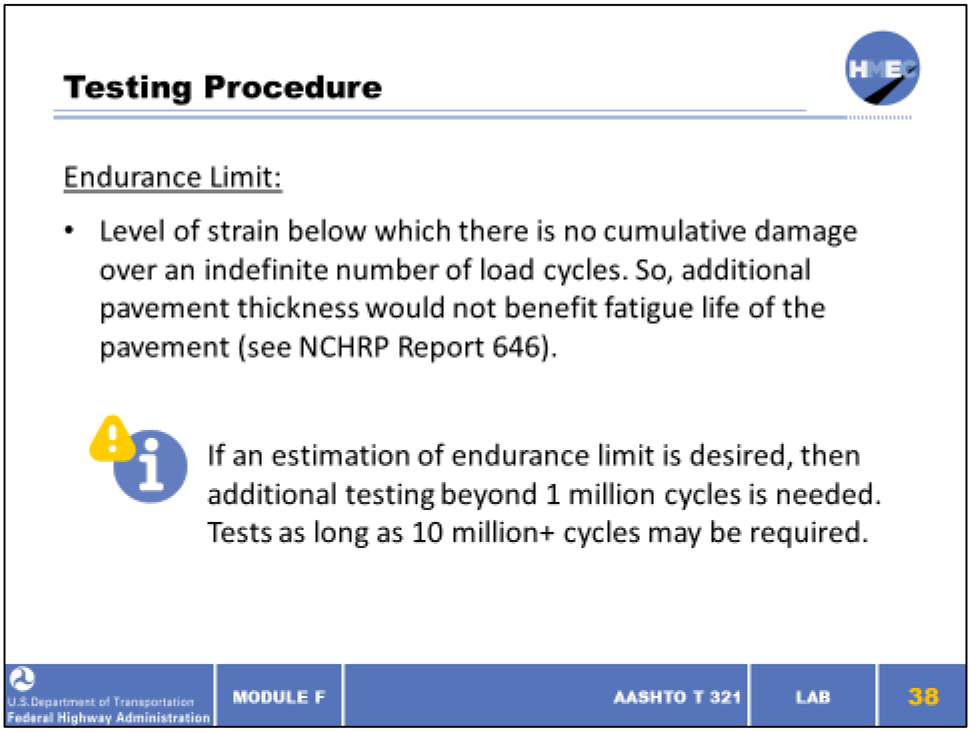
Testing Procedure
HMEC
Endurance Limit:
• Level of strain below which there is no cumulative damage over an indefinite number of load cycles. So, additional pavement thickness would not benefit fatigue life of the pavement (see NCHRP Report 646).
If an estimation of endurance limit is desired, then additional testing beyond 1 million cycles is needed. Tests as long as 10 million+ cycles may be required.
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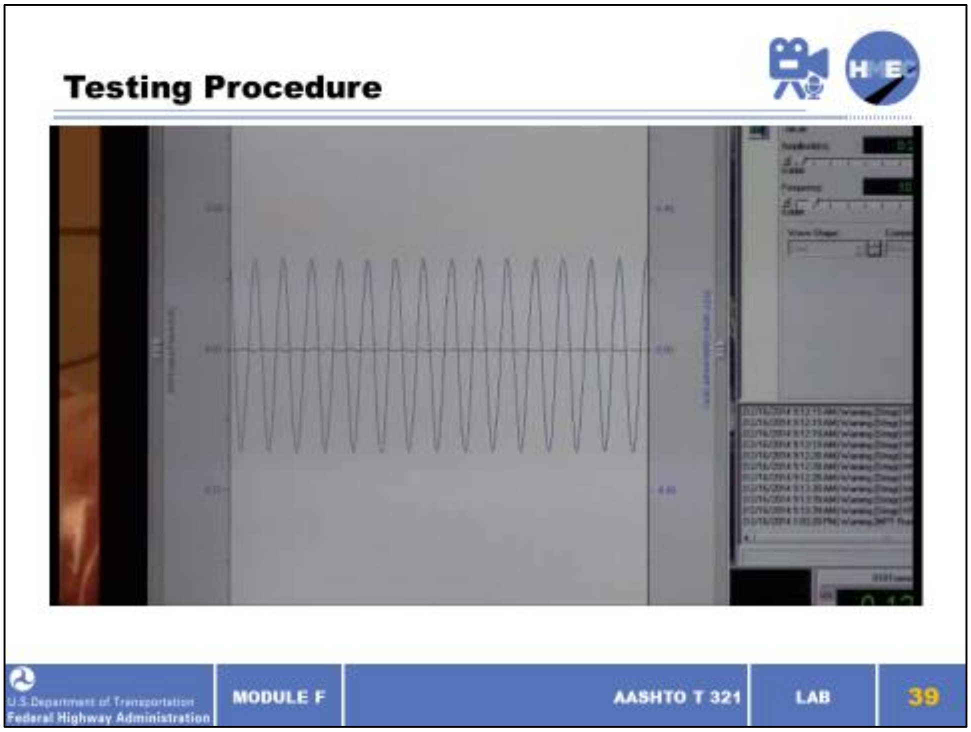
Testing Procedure
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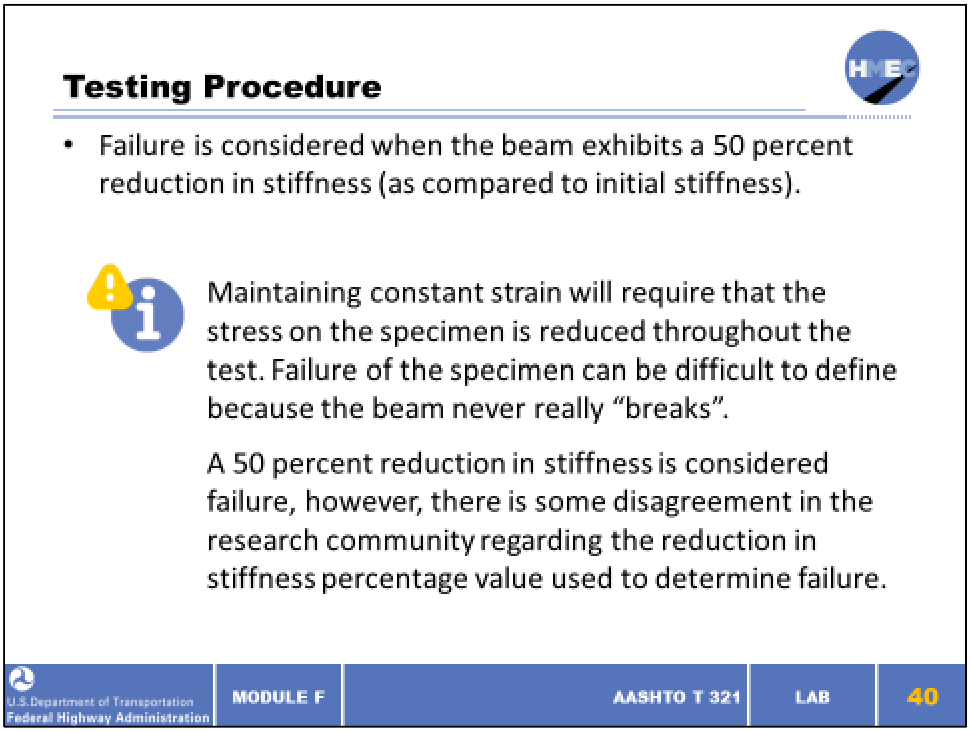
Testing Procedure
HMEC
• Failure is considered when the beam exhibits a 50 percent reduction in stiffness (as compared to initial stiffness).
Maintaining constant strain will require that the stress on the specimen is reduced throughout the test. Failure of the specimen can be difficult to define because the beam never really "breaks".
A 50 percent reduction in stiffness is considered failure, however, there is some disagreement in the research community regarding the reduction in stiffness percentage value used to determine failure.
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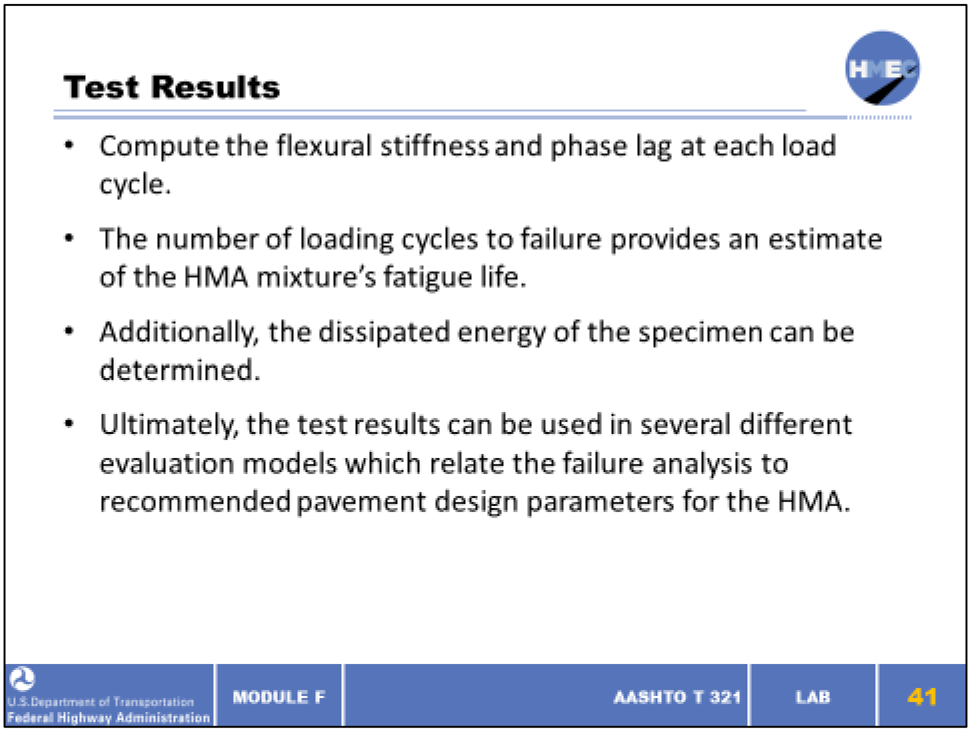
Test Results
HMEC
• Compute the flexural stiffness and phase lag at each load cycle.
• The number of loading cycles to failure provides an estimate of the HMA mixture's fatigue life.
• Additionally, the dissipated energy of the specimen can be determined.
• Ultimately, the test results can be used in several different evaluation models which relate the failure analysis to recommended pavement design parameters for the HMA.
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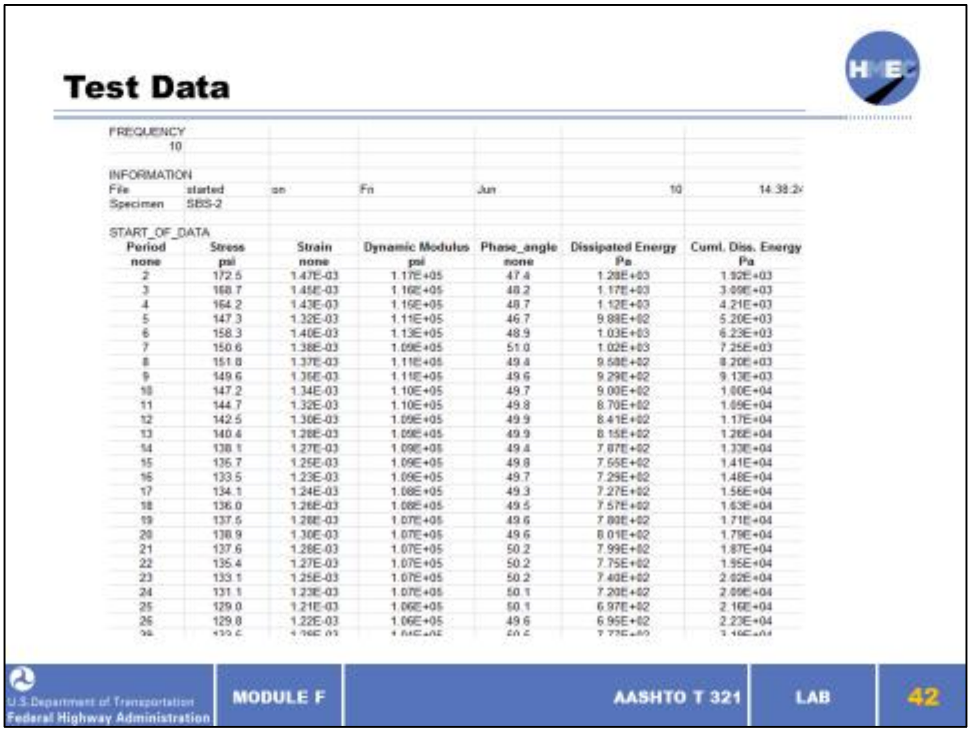

FREQUENCY
10

INFORMATION

File	started	on	Fri	Jun	10	14:38:2
Specimen	SBS-2					

START_OF_DATA

Period none	Stress psi	Strain none	Dynamic Modulus psi	Phase_angle none	Dissipated Energy Pa	Cuml. Diss. Energy Pa
2	172.5	1.47E-03	1.17E+05	47.4	1.28E+03	1.92E+03
3	168.7	1.45E-03	1.16E+05	48.2	1.17E+03	3.09E+03
4	164.2	1.43E-03	1.15E+05	48.7	1.12E+03	4.21E+03
5	147.3	1.32E-03	1.11E+05	46.7	9.88E+02	5.20E+03
6	158.3	1.40E-03	1.13E+05	48.9	1.03E+03	6.23E+03
7	150.6	1.38E-03	1.09E+05	51.0	1.02E+03	7.25E+03
8	151.8	1.37E-03	1.11E+05	49.4	9.58E+02	8.20E+03
9	149.6	1.36E-03	1.11E+05	49.6	9.29E+02	9.13E+03
10	147.2	1.34E-03	1.10E+05	49.7	9.00E+02	1.00E+04
11	144.7	1.32E-03	1.10E+05	49.8	8.70E+02	1.09E+04
12	142.5	1.30E-03	1.09E+05	49.9	8.41E+02	1.17E+04
13	140.4	1.28E-03	1.09E+05	49.9	8.15E+02	1.26E+04
14	138.1	1.27E-03	1.09E+05	49.4	7.87E+02	1.33E+04
15	136.7	1.25E-03	1.09E+05	49.8	7.55E+02	1.41E+04
16	133.5	1.23E-03	1.09E+05	49.7	7.29E+02	1.48E+04
17	134.1	1.24E-03	1.08E+05	49.3	7.27E+02	1.56E+04
18	136.0	1.26E-03	1.08E+05	49.5	7.57E+02	1.63E+04
19	137.5	1.28E-03	1.07E+05	49.6	7.80E+02	1.71E+04
20	138.9	1.30E-03	1.07E+05	49.6	8.01E+02	1.79E+04
21	137.6	1.28E-03	1.07E+05	50.2	7.99E+02	1.87E+04
22	135.4	1.27E-03	1.07E+05	50.2	7.75E+02	1.95E+04
23	133.1	1.25E-03	1.07E+05	50.2	7.40E+02	2.02E+04
24	131.1	1.23E-03	1.07E+05	50.1	7.20E+02	2.09E+04
25	129.0	1.21E-03	1.06E+05	50.1	6.97E+02	2.16E+04
26	129.8	1.22E-03	1.06E+05	49.6	6.95E+02	2.23E+04

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Test Results

- Compute the flexural stiffness, phase lag and the following for each load cycle:

Load Cycle	Applied Load N	Beam Deflection m	Peak-to-Peak Stress Pa	Peak-to-Peak Strain m/m	Flexural Stiffness MPa	Phase Angle degree	$S \times n$

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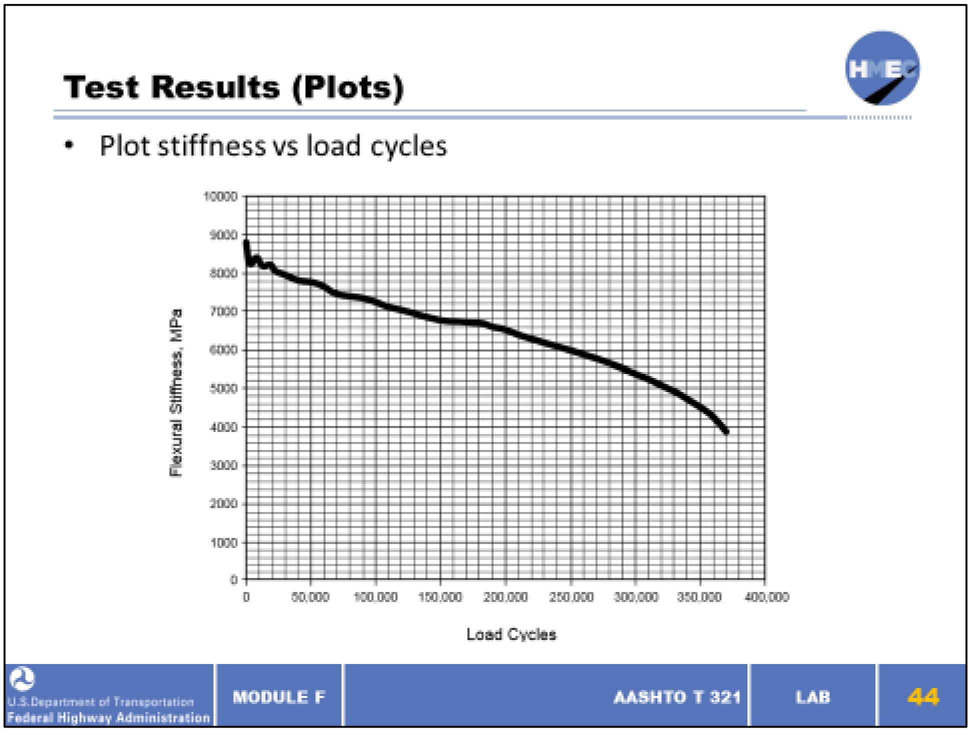
Test Results (Plots)
• Plot stiffness vs load cycles
Flexural Stiffness, MPa
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
50,000
100,000
150,000
200,000
250,000
300,000
350,000
400,000
Load Cycles
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Questions?
HMEC
Q&A
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AASHTO T 322

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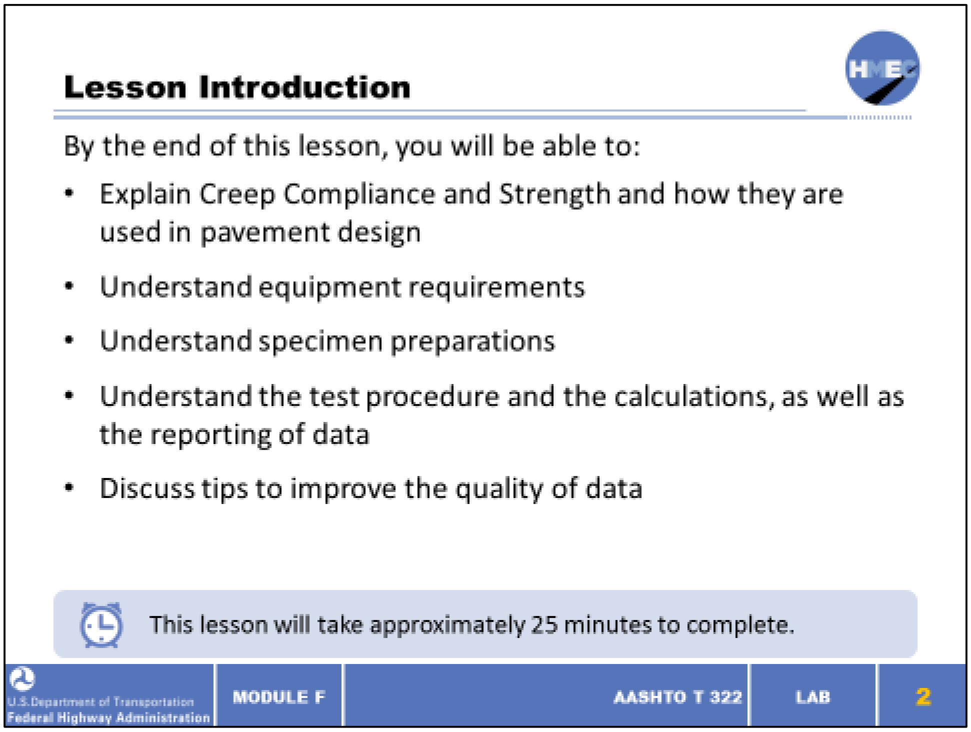
Slide 2


Lesson Introduction
By the end of this lesson, you will be able to:
• Explain Creep Compliance and Strength and how they are used in pavement design
• Understand equipment requirements
• Understand specimen preparations
• Understand the test procedure and the calculations, as well as the reporting of data
• Discuss tips to improve the quality of data
This lesson will take approximately 25 minutes to complete.
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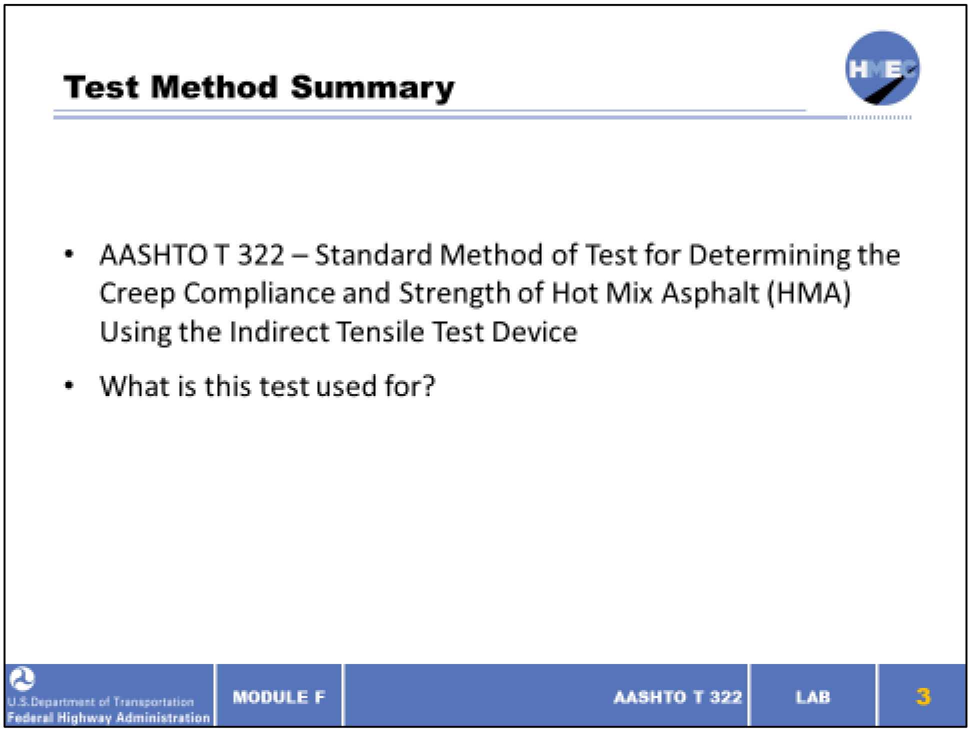
Test Method Summary
HMEC
• AASHTO T 322 – Standard Method of Test for Determining the Creep Compliance and Strength of Hot Mix Asphalt (HMA) Using the Indirect Tensile Test Device
• What is this test used for?
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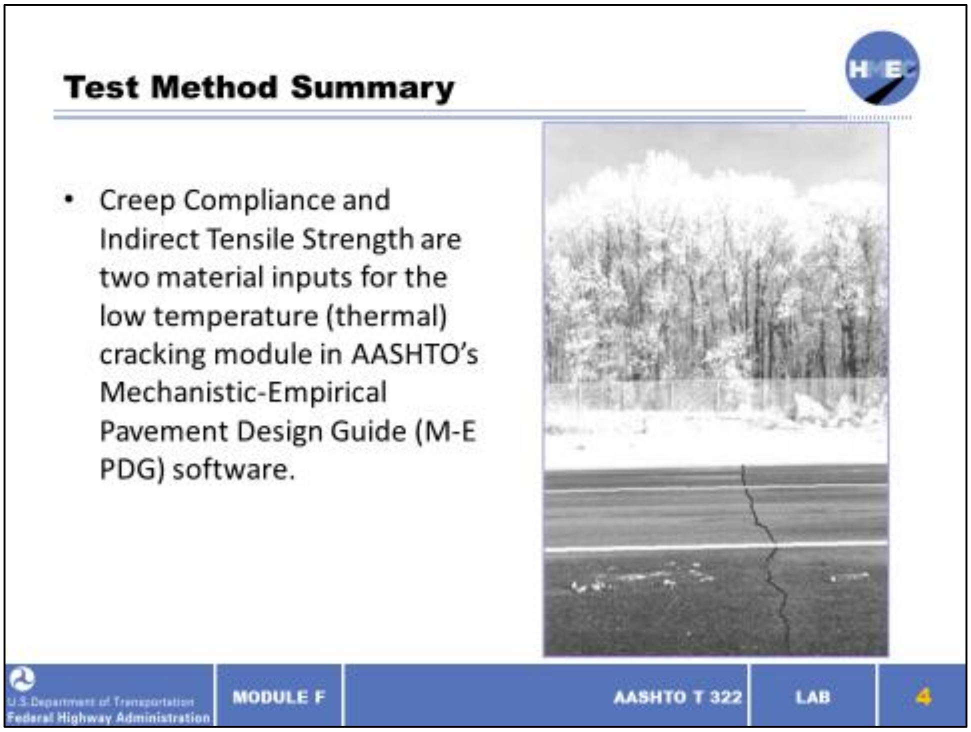
Test Method Summary
• Creep Compliance and Indirect Tensile Strength are two material inputs for the low temperature (thermal) cracking module in AASHTO's Mechanistic-Empirical Pavement Design Guide (M-E PDG) software.
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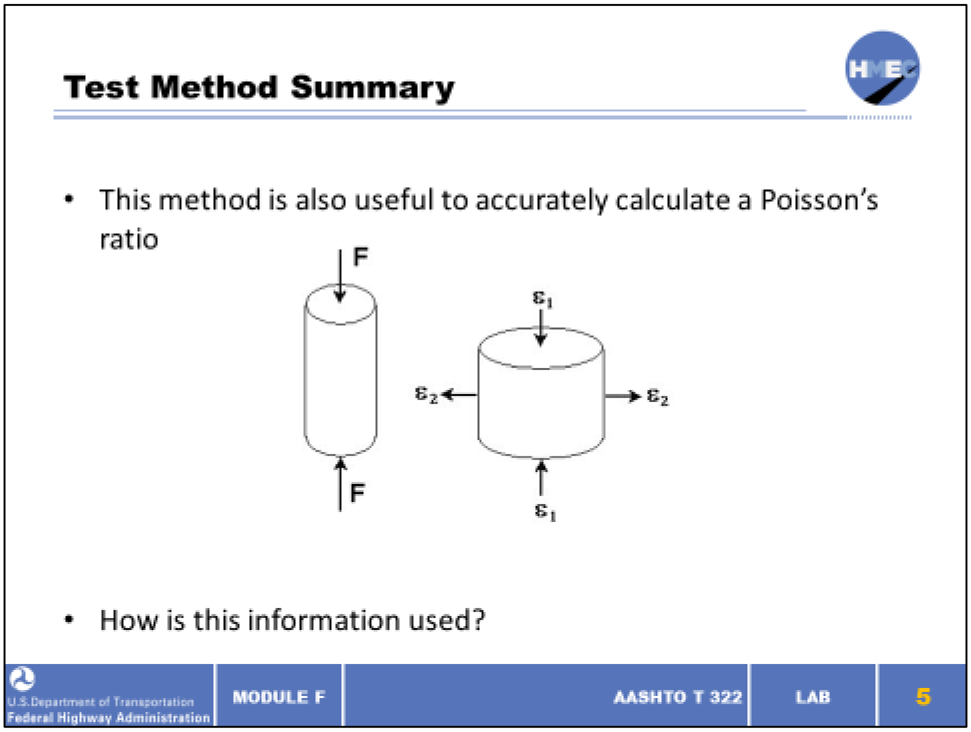
Test Method Summary
HMEC
• This method is also useful to accurately calculate a Poisson's ratio
F
F
ε1
ε1
ε2
ε2
• How is this information used?
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Test Method Summary

- The creep compliance, tensile strength, and Poisson's ratio can be used in linear viscoelastic analysis to calculate the low temperature thermal cracking potential
- Tensile Creep and Tensile Strength data is used to determine the master relaxation modulus curve and fracture parameters
- Master relaxation modulus curve controls thermal crack development
- Fracture parameter defines a mixture's resistance to fracture
- Tensile creep data can also be used to evaluate the relative quality of materials.

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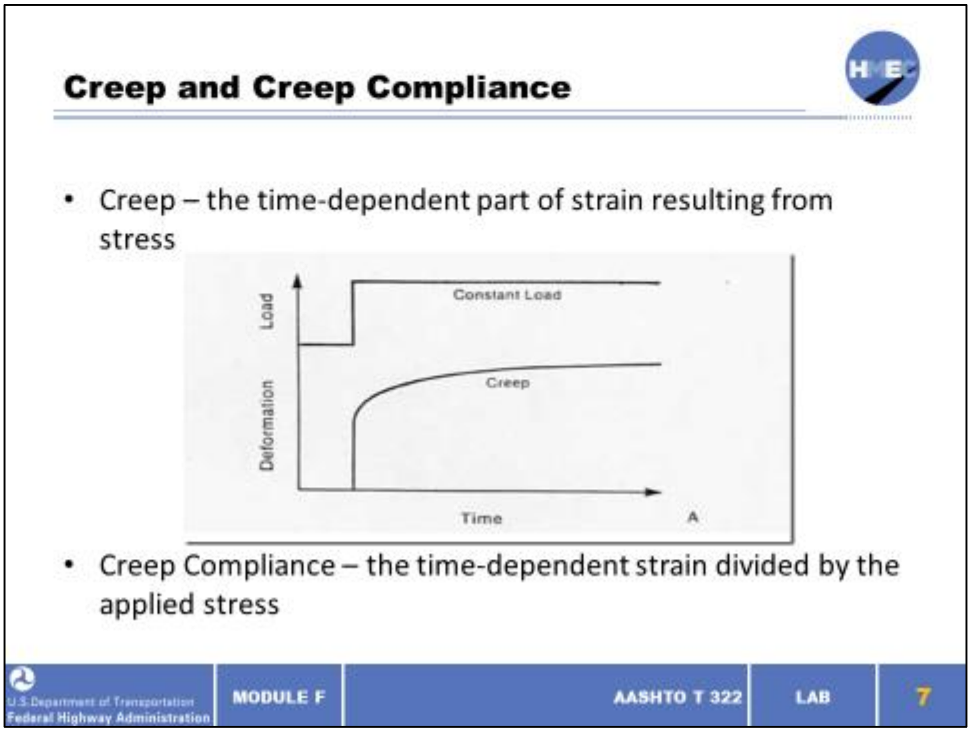
Creep and Creep Compliance
• Creep – the time-dependent part of strain resulting from stress
Load
Constant Load
Deformation
Creep
Time
A
• Creep Compliance – the time-dependent strain divided by the applied stress
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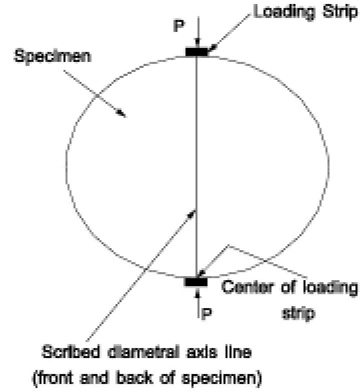
Tensile Strength

- Tensile Strength – The strength shown by a specimen subjected to tension, as distinct from torsion, compression, or shear



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Equipment Requirements

- Indirect Tensile Test System consists of:
  - Axial Loading Device
  - Load Measuring Device
  - Specimen Deformation Measurement Devices
  - Environmental Chamber
  - Control and Data Acquisition System
  - Gauge Points
  - Mounting Template
  - Test Specimen Loading Frame

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Equipment Requirements

- Axial Loading Device
  - Capable of providing a constant load of 100 kN with a resolution of at least 20 kN
  - Capable of a constant ram displacement of 12 mm/min

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Equipment Requirements
• Load Measuring Device
– Electronic load cell with a sensitivity of 20 kN and a minimum capacity of 100 kN
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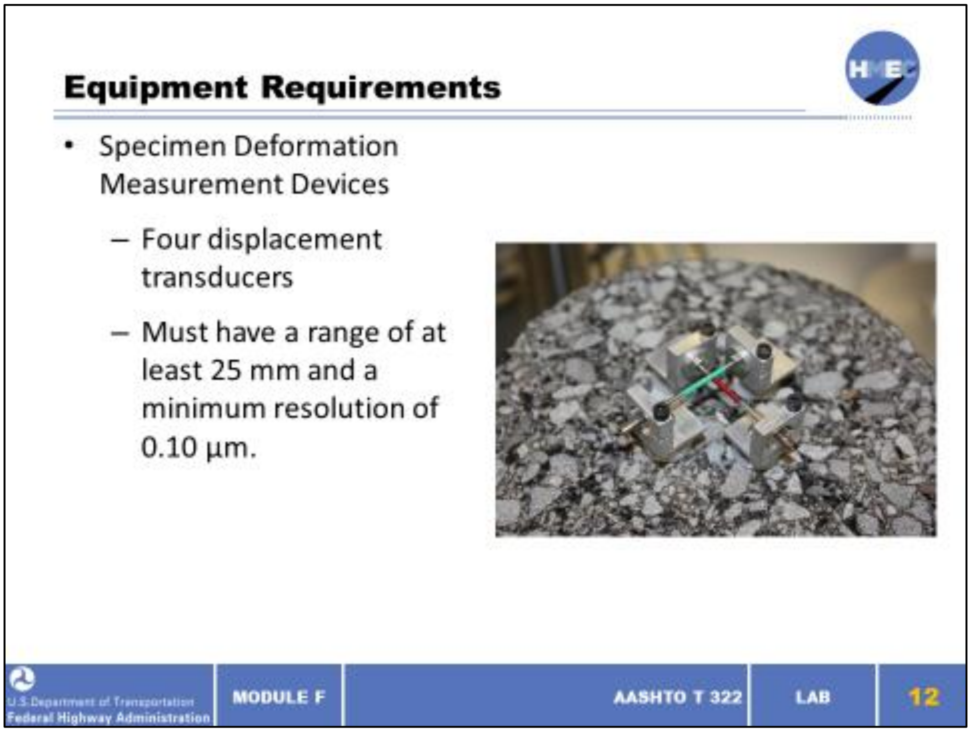
Equipment Requirements
• Specimen Deformation Measurement Devices
– Four displacement transducers
– Must have a range of at least 25 mm and a minimum resolution of 0.10 µm.
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Equipment Requirements

- Environmental Chamber
  - Capable of generating test temperatures between -30°C and +10°C
  - Must be capable of holding the desired temperature to ±0.5°C
  - Must be large enough to hold a minimum of 3 specimens for 12 hours prior to testing

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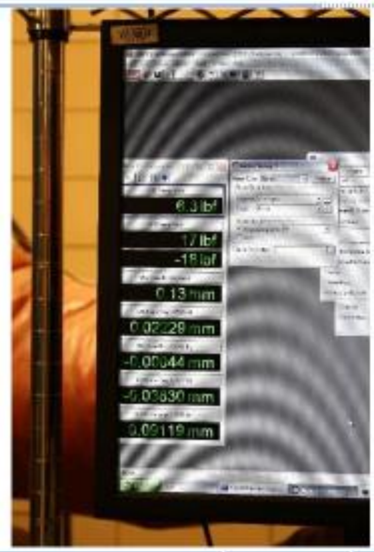
Equipment Requirements

- Control and Data Acquisition System
  - Must be capable of recording applied load and specimen deformation at the frequencies specified in section 6.1.5.1



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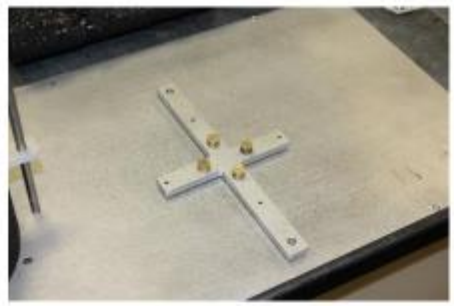
Equipment Requirements

- Gauge Points
  - 8 brass gauge points required per specimen
  - Diameter of 8 mm and a height of 3.2 mm
- Mounting Template
  - Used to place and mount the brass gauge points to each side of the specimens
  - A template can be found in Figure 1 of T 322



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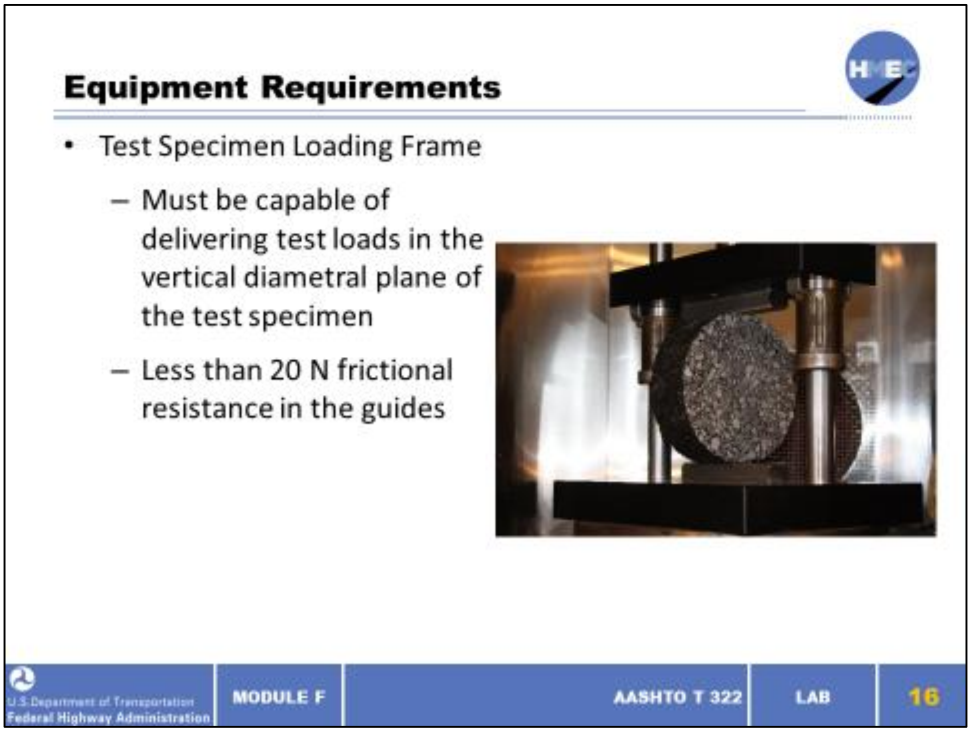
Equipment Requirements
• Test Specimen Loading Frame
– Must be capable of delivering test loads in the vertical diametral plane of the test specimen
– Less than 20 N frictional resistance in the guides
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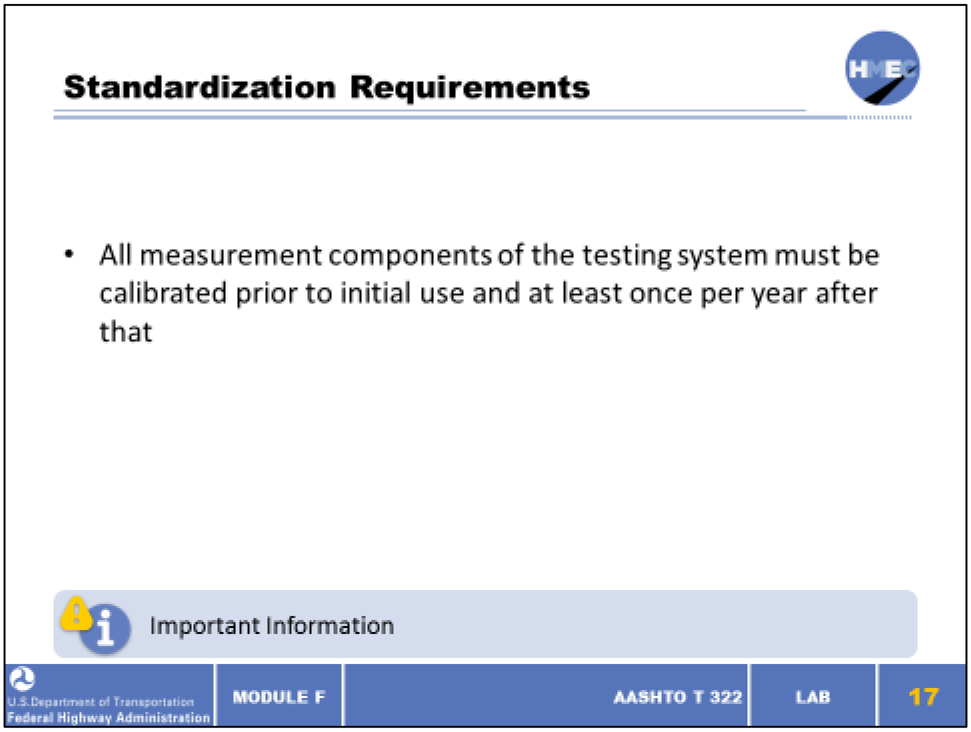
Standardization Requirements
HMEC
• All measurement components of the testing system must be calibrated prior to initial use and at least once per year after that
Important Information
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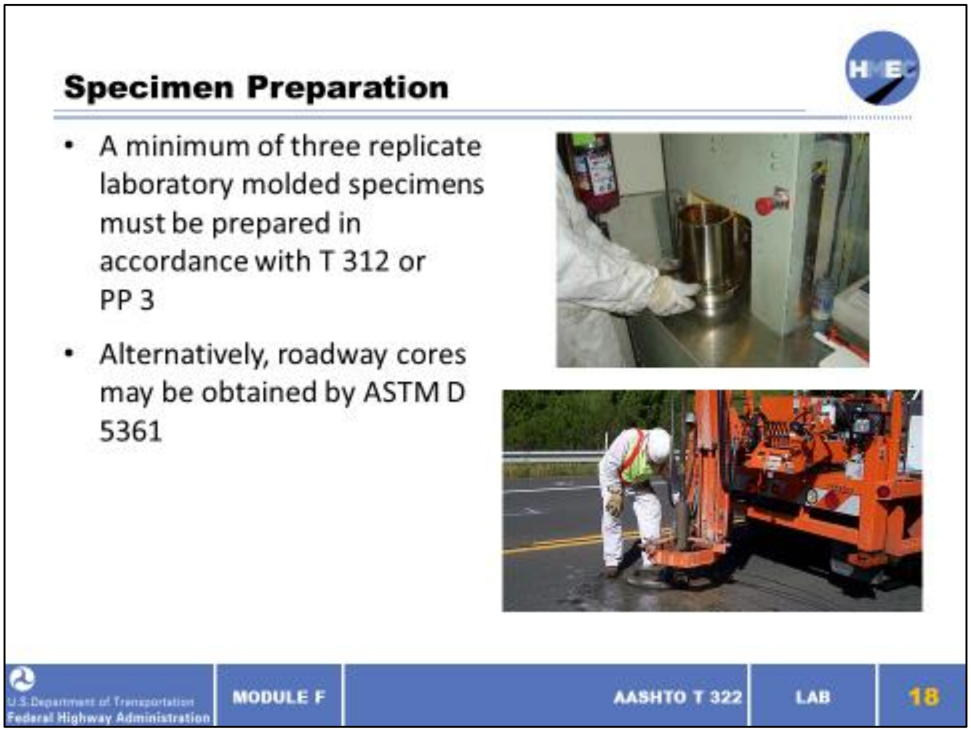
Specimen Preparation
• A minimum of three replicate laboratory molded specimens must be prepared in accordance with T 312 or PP 3
• Alternatively, roadway cores may be obtained by ASTM D 5361
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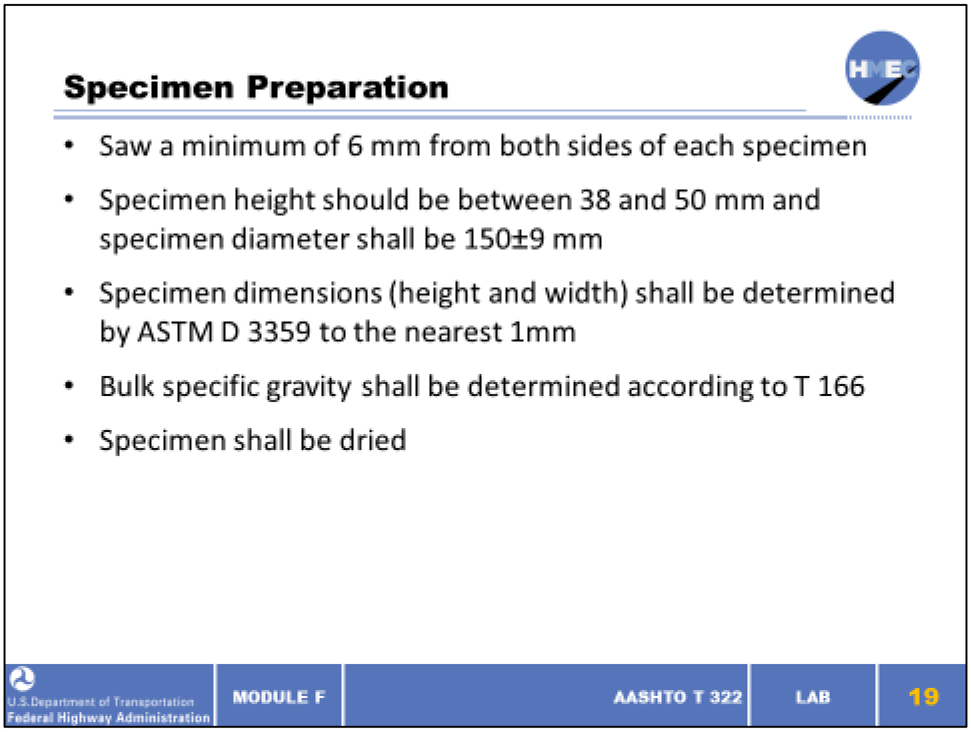
Specimen Preparation
HMEC
• Saw a minimum of 6 mm from both sides of each specimen
• Specimen height should be between 38 and 50 mm and specimen diameter shall be 150±9 mm
• Specimen dimensions (height and width) shall be determined by ASTM D 3359 to the nearest 1mm
• Bulk specific gravity shall be determined according to T 166
• Specimen shall be dried
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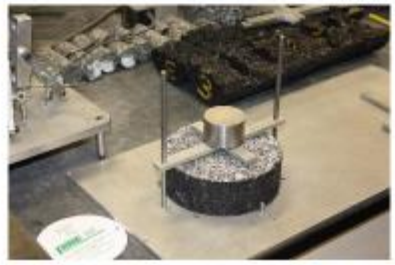
Specimen Preparation

- Brass gauge points shall be applied with epoxy (four per face per specimen) with two along the vertical axis and two along the horizontal axis
- Placement and location of the gauge points shall produce a mirror image of each other



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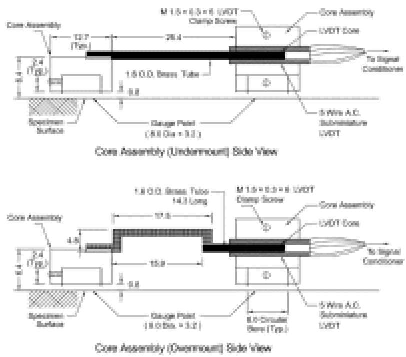
Specimen Preparation

- Mount the displacement transducers so that the transducer's center line is 6.4 mm above the specimen surface



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Testing Procedure

- The tensile creep compliance of each specimen shall be measured at three different temperatures at 10°C intervals
- Recommended test temperatures are based on the binder grade used in the mix

Binder Grade Used in the Mix	Recommended Temperatures
PG XX-34 or softer	-30, -20, and -10°C
PG XX-28, PG XX-22, or if the grade is unknown	-20, -10, and 0°C
PG XX-16 or harder	-10, 0, and 10°C
Any material that has been severely aged	Increase test temperatures by 10°C

- M-E PDG input requirements are -20, -10 and 0°C

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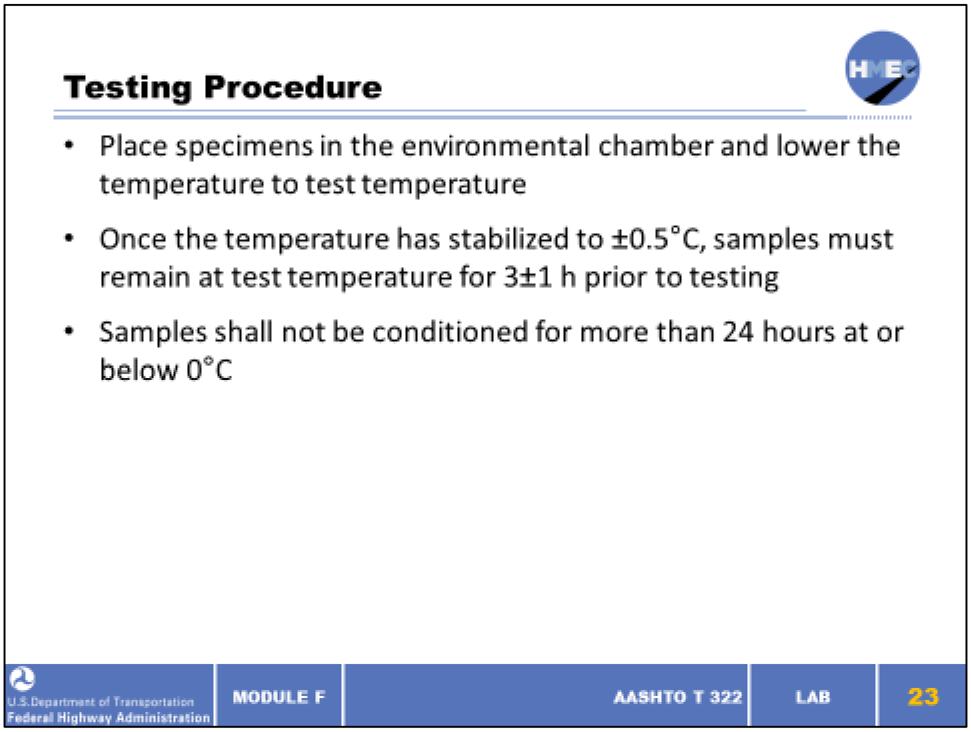
Testing Procedure
• Place specimens in the environmental chamber and lower the temperature to test temperature
• Once the temperature has stabilized to ±0.5°C, samples must remain at test temperature for 3±1 h prior to testing
• Samples shall not be conditioned for more than 24 hours at or below 0°C
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Testing Procedure

- Apply a static load of fixed magnitude without impact to the specimen for 100 ± 2 seconds
- The fixed load should produce a horizontal deformation of 0.00125 mm to 0.0190 mm for a 150 mm specimen
- Violating the upper limit can cause a nonlinear response
- Violating the lower limit causes problems with background noise and drift inherent in the sensors
- If either limit is violated, remove test shall be stopped and the specimen shall be allowed to rest for 5 minutes before a new load is applied

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Testing Procedure
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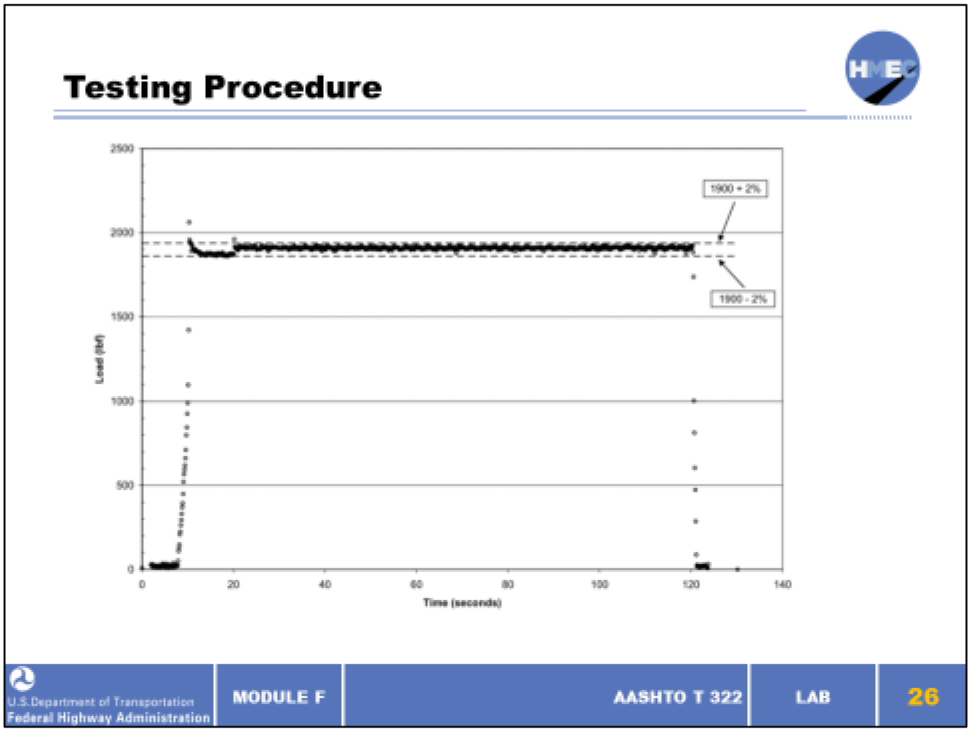
Testing Procedure
HMEC
2500
2000
1500
1000
500
0
Load (lbf)
1900 + 2%
1900 - 2%
0
20
40
60
80
100
120
140
Time (seconds)
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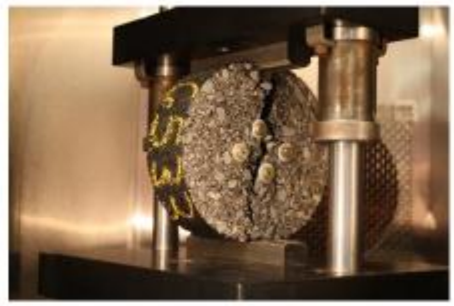
Testing Procedure

- After creep tests have been conducted at each temperature, the tensile strength of each specimen shall be determined at the middle temperature
- Ram speed should be 12.5 mm/min



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Testing Procedure
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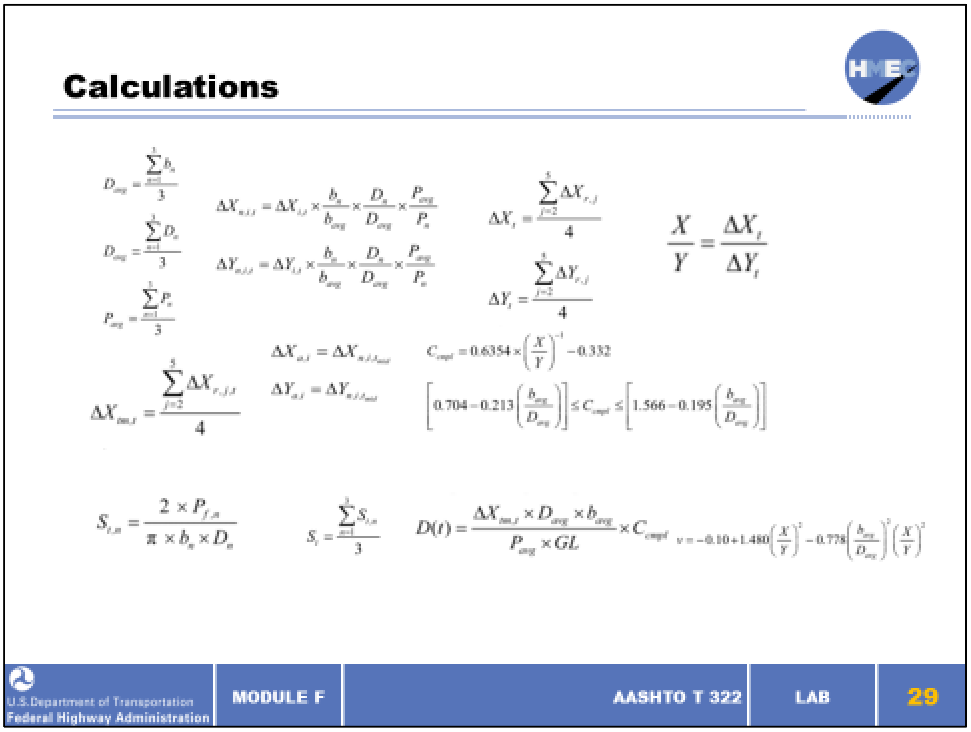
Calculations
$D_{avg} = \frac{\sum_{n=1}^{3} b_n}{3}$
$D_{avg} = \frac{\sum_{n=1}^{3} D_n}{3}$
$P_{avg} = \frac{\sum_{n=1}^{3} P_n}{3}$
$\Delta X_{n,i,j} = \Delta X_{i,j} \times \frac{b_n}{b_{avg}} \times \frac{D_n}{D_{avg}} \times \frac{P_{avg}}{P_n}$
$\Delta Y_{n,i,j} = \Delta Y_{i,j} \times \frac{b_n}{b_{avg}} \times \frac{D_n}{D_{avg}} \times \frac{P_{avg}}{P_n}$
$\Delta X_t = \frac{\sum_{j=2}^{5} \Delta X_{r,j}}{4}$
$\Delta Y_t = \frac{\sum_{j=2}^{5} \Delta Y_{r,j}}{4}$
$\frac{X}{Y} = \frac{\Delta X_t}{\Delta Y_t}$
$\Delta X_{a,t} = \Delta X_{n,i,t_{md}}$
$\Delta Y_{a,t} = \Delta Y_{n,i,t_{md}}$
$\Delta X_{m,t} = \frac{\sum_{j=2}^{5} \Delta X_{r,j,t}}{4}$
$C_{cmpl} = 0.6354 \times \left(\frac{X}{Y}\right)^{-1} - 0.332$
$\left[0.704 - 0.213\left(\frac{b_{avg}}{D_{avg}}\right)\right] \leq C_{cmpl} \leq \left[1.566 - 0.195\left(\frac{b_{avg}}{D_{avg}}\right)\right]$
$S_{t,n} = \frac{2 \times P_{f,n}}{\pi \times b_n \times D_n}$
$S_t = \frac{\sum_{n=1}^{3} S_{t,n}}{3}$
$D(t) = \frac{\Delta X_{m,t} \times D_{avg} \times b_{avg}}{P_{avg} \times GL} \times C_{cmpl}$
$v = -0.10 + 1.480\left(\frac{X}{Y}\right)^2 - 0.778\left(\frac{b_{avg}}{D_{avg}}\right)^2\left(\frac{X}{Y}\right)^2$
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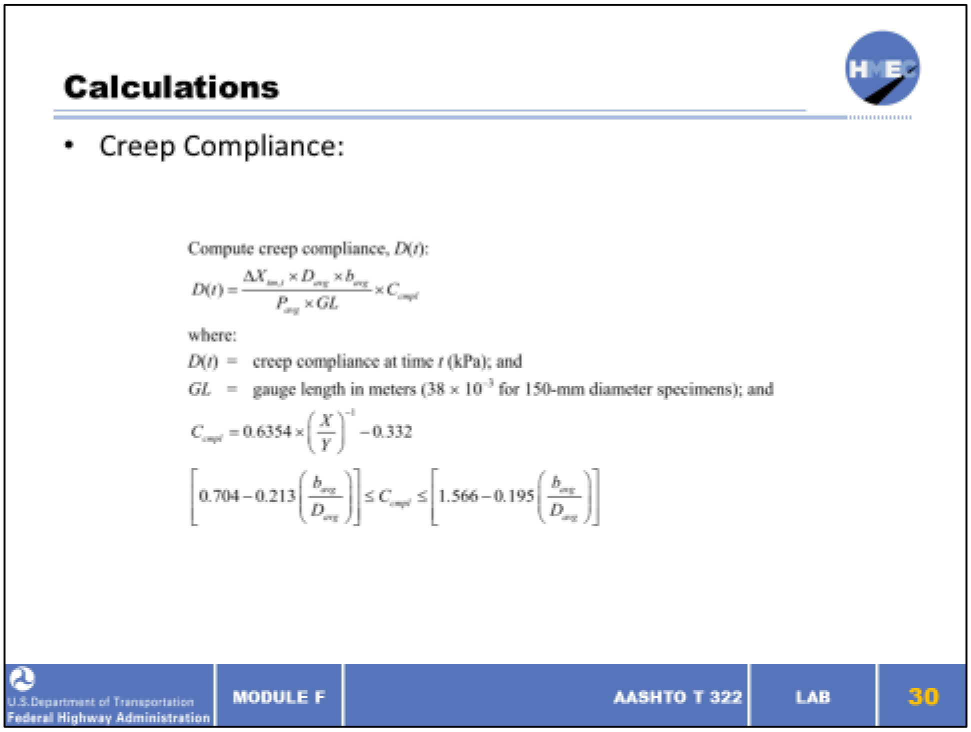
Calculations
• Creep Compliance:
Compute creep compliance, $D(t)$:
$D(t) = \frac{\Delta X_{tm,t} \times D_{avg} \times b_{avg}}{P_{avg} \times GL} \times C_{cmpl}$
where:
$D(t)$ = creep compliance at time t (kPa); and
GL = gauge length in meters (38×10^{-3} for 150-mm diameter specimens); and
$C_{cmpl} = 0.6354 \times \left(\frac{X}{Y}\right)^{-1} - 0.332$
$\left[0.704 - 0.213\left(\frac{b_{avg}}{D_{avg}}\right)\right] \le C_{cmpl} \le \left[1.566 - 0.195\left(\frac{b_{avg}}{D_{avg}}\right)\right]$
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Calculations

- Poisson's Ratio:

Poisson's ratio, ν, may be computed as:

$$v = -0.10 + 1.480\left(\frac{X}{Y}\right)^2 - 0.778\left(\frac{b_{avg}}{D_{avg}}\right)^2\left(\frac{X}{Y}\right)^2$$

where:

$0.05 \le v \le 0.50$

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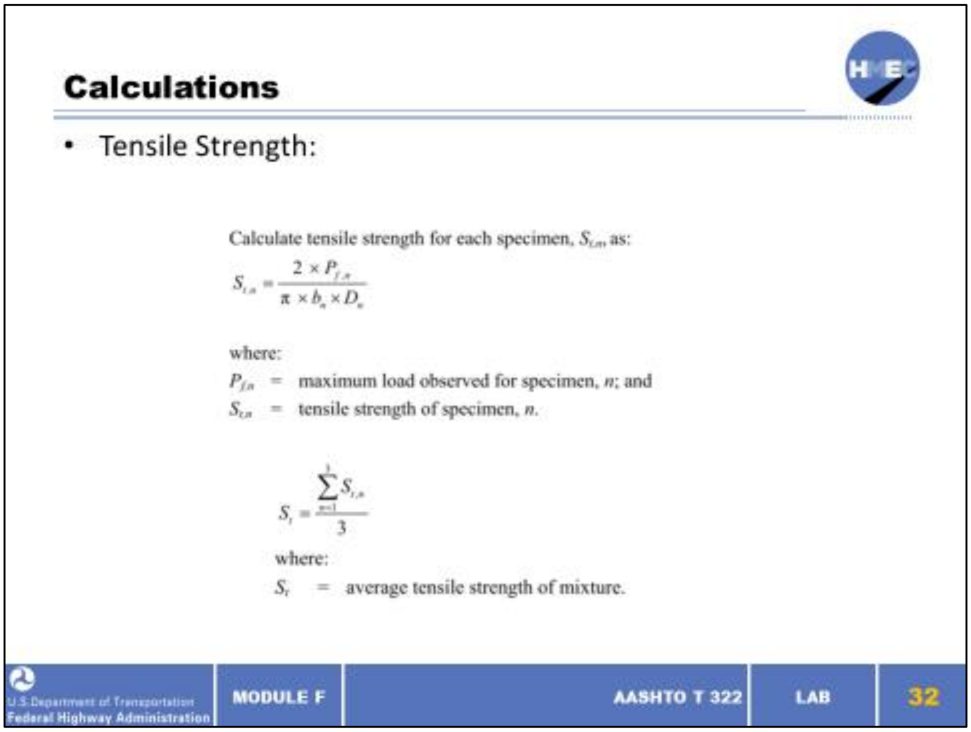
Calculations
• Tensile Strength:
Calculate tensile strength for each specimen, $S_{t,n}$, as:
$S_{t,n} = \frac{2 \times P_{f,n}}{\pi \times b_n \times D_n}$
where:
$P_{f,n}$ = maximum load observed for specimen, n; and
$S_{t,n}$ = tensile strength of specimen, n.
$S_t = \frac{\sum_{n=1}^{3} S_{t,n}}{3}$
where:
S_t = average tensile strength of mixture.
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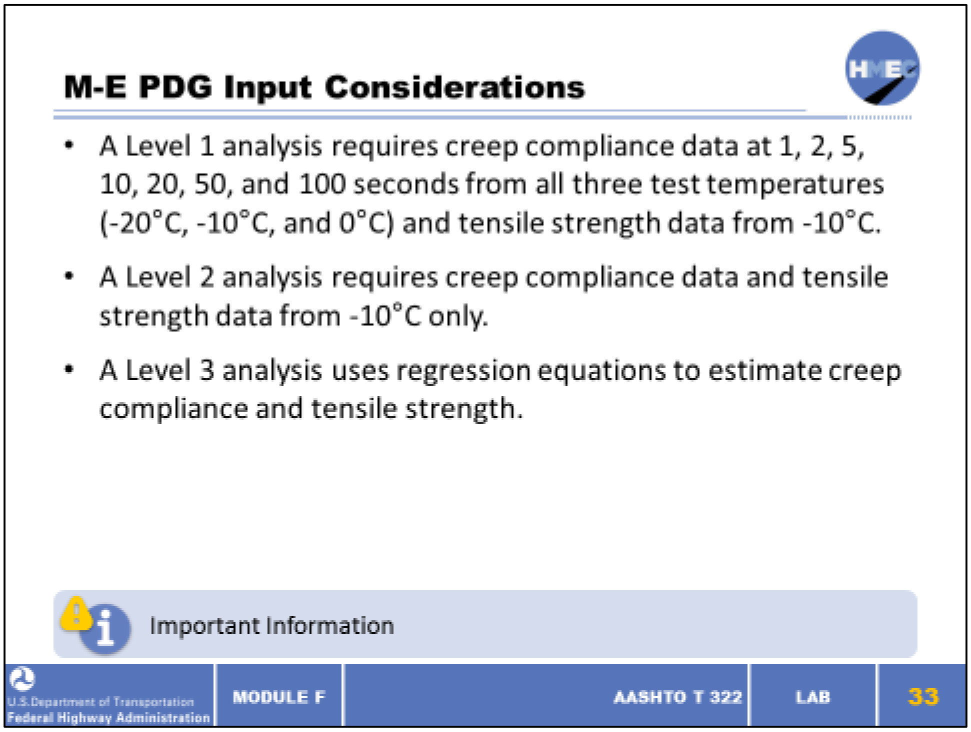
M-E PDG Input Considerations
HMEC
A Level 1 analysis requires creep compliance data at 1, 2, 5, 10, 20, 50, and 100 seconds from all three test temperatures (-20°C, -10°C, and 0°C) and tensile strength data from -10°C.
A Level 2 analysis requires creep compliance data and tensile strength data from -10°C only.
A Level 3 analysis uses regression equations to estimate creep compliance and tensile strength.
Important Information
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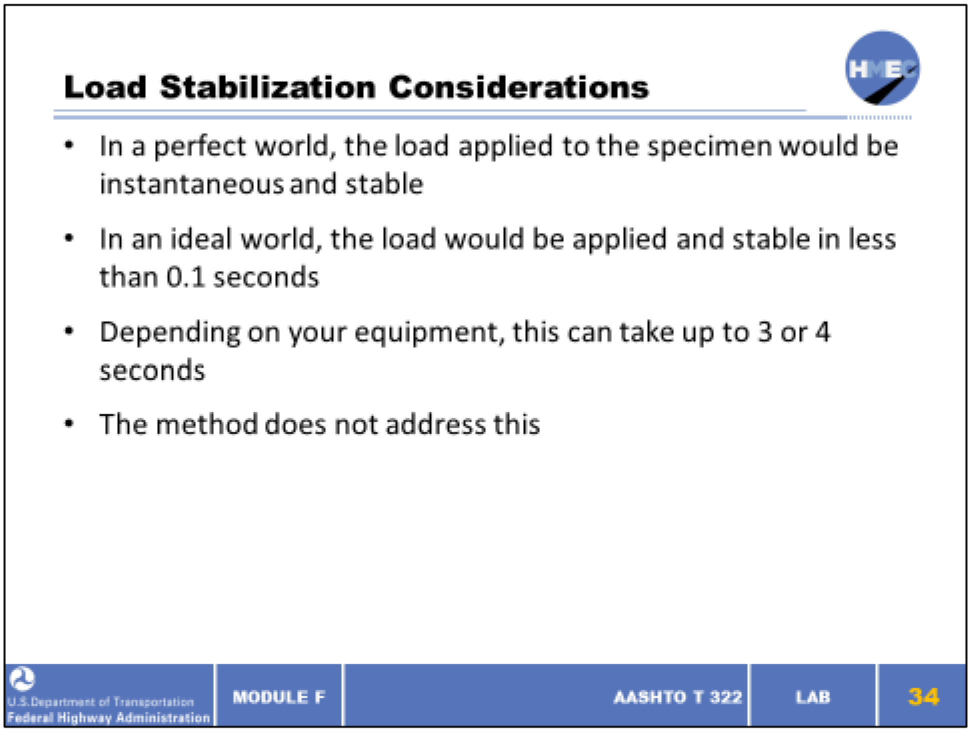
Load Stabilization Considerations
HMEC
• In a perfect world, the load applied to the specimen would be instantaneous and stable
• In an ideal world, the load would be applied and stable in less than 0.1 seconds
• Depending on your equipment, this can take up to 3 or 4 seconds
• The method does not address this
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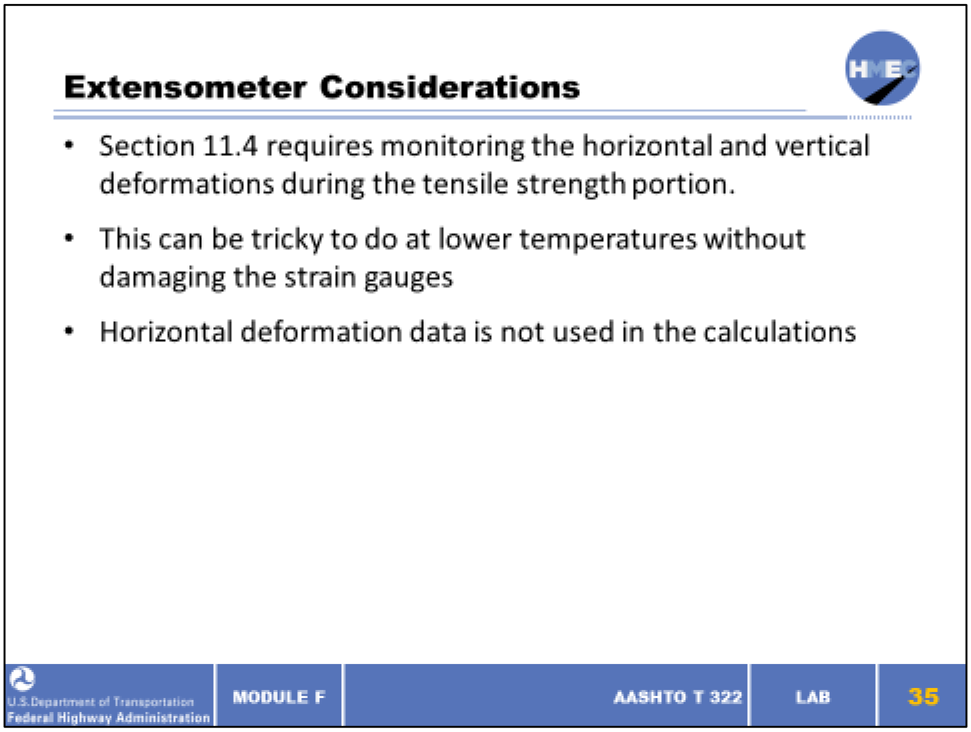
Extensometer Considerations
HMEC
• Section 11.4 requires monitoring the horizontal and vertical deformations during the tensile strength portion.
• This can be tricky to do at lower temperatures without damaging the strain gauges
• Horizontal deformation data is not used in the calculations
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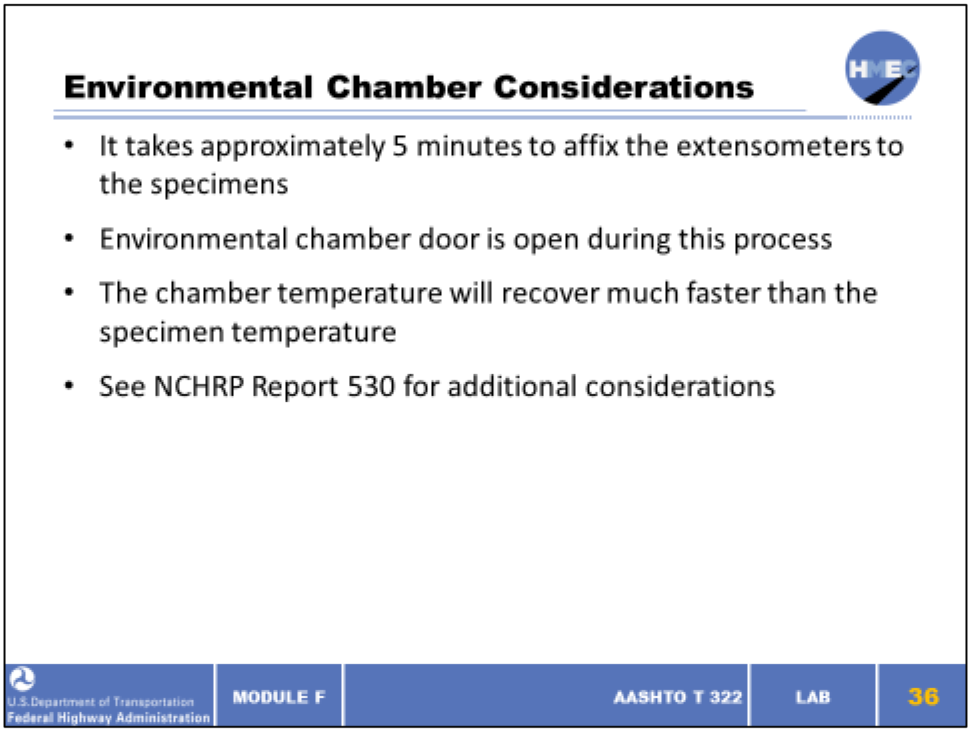
Environmental Chamber Considerations
HMEC
It takes approximately 5 minutes to affix the extensometers to the specimens
Environmental chamber door is open during this process
The chamber temperature will recover much faster than the specimen temperature
See NCHRP Report 530 for additional considerations
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Lesson Summary

You are now able to:

- Explain Creep Compliance and Strength and how they are used in pavement design
- Understand equipment requirements
- Understand specimen preparations
- Understand the test procedure and the calculations, as well as the reporting of data
- Discuss tips to improve the quality of data

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Questions
Questions?
Q&A
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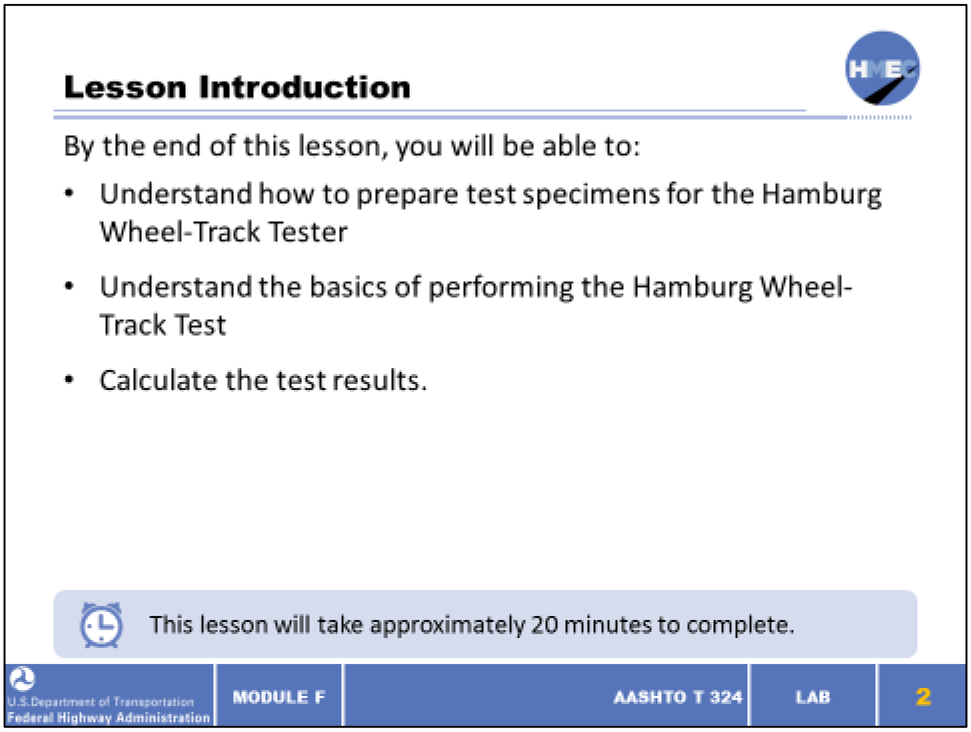
AASHTO T 324

Slide 1

Slide 2


Lesson Introduction
By the end of this lesson, you will be able to:
• Understand how to prepare test specimens for the Hamburg Wheel-Track Tester
• Understand the basics of performing the Hamburg Wheel-Track Test
• Calculate the test results.
This lesson will take approximately 20 minutes to complete.
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History

- Developed in the 1970's in Hamburg, Germany.
- Inventor was E.G. Esso.
- Test has been gradually gaining acceptance throughout the United States.
- Originally called the Esso Wheel-Tracking Device
- Based on a smaller British rolling-wheel device with a rubber tire.
- Developed to determine rutting susceptibility of pavements for the city of Hamburg.
- Test later improved by other users, including research completed by FHWA.

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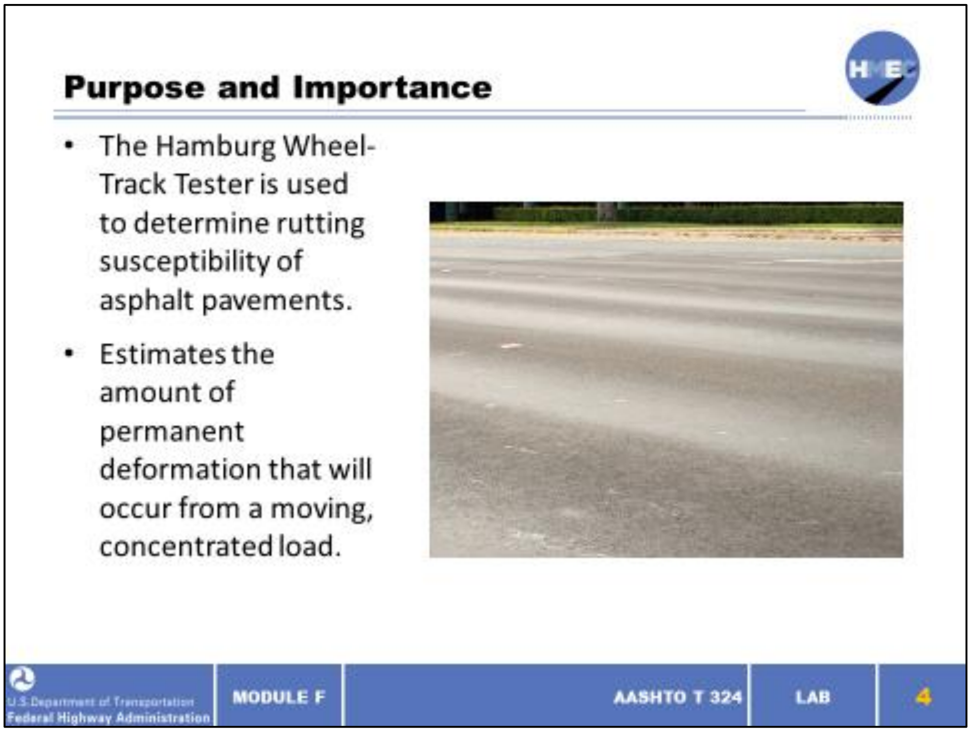
Purpose and Importance
• The Hamburg Wheel-Track Tester is used to determine rutting susceptibility of asphalt pavements.
• Estimates the amount of permanent deformation that will occur from a moving, concentrated load.
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Rutting

- Deformation in the wheel path from repeated loading cycles.
- Rutting in the asphalt mixture layer can be caused by:
  - Insufficient compaction
  - Excessive asphalt content
  - Too much mineral filler
  - Aggregate shape
  - Moisture susceptibility

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Environmental Conditions and Rutting

- The performance of any particular mix design is greatly affected by
  - Traffic loading
  - Climactic conditions

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Apparatus – Testing Device

- 8-in diameter, 1.85 in. wide steel wheel.
- Applies load of 158 ± 1 lb.

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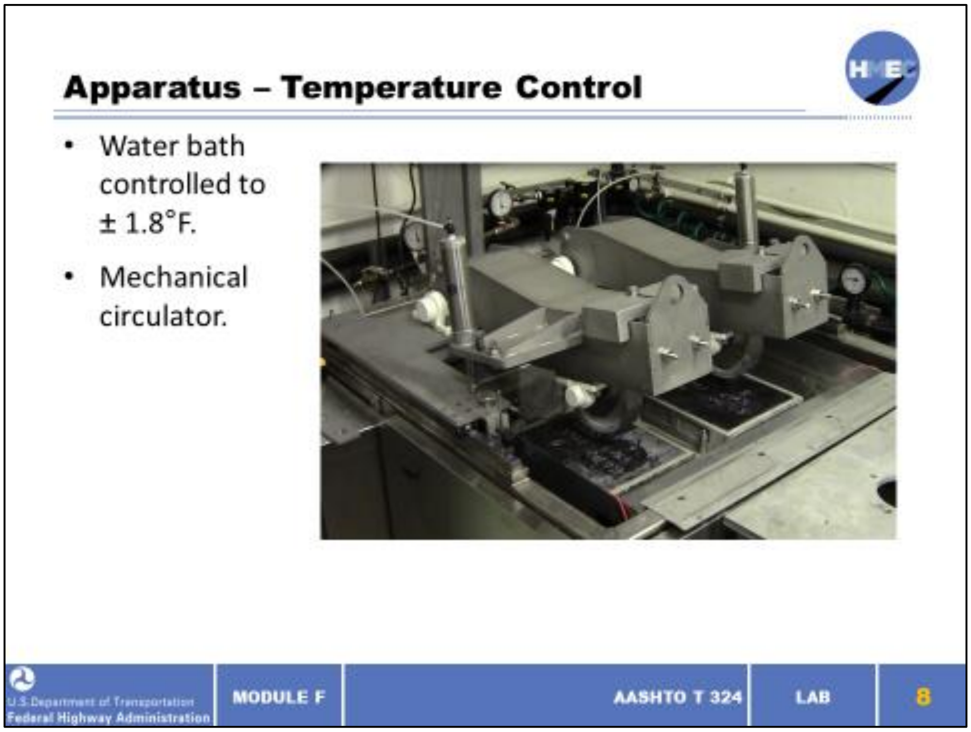
Apparatus – Temperature Control
• Water bath controlled to ± 1.8°F.
• Mechanical circulator.
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Apparatus – Impression Measurement System

- LVDT for measuring rut depth.
- Measured at center along the length of the wheel's path.
- Rut depth measured at least every 400 passes.

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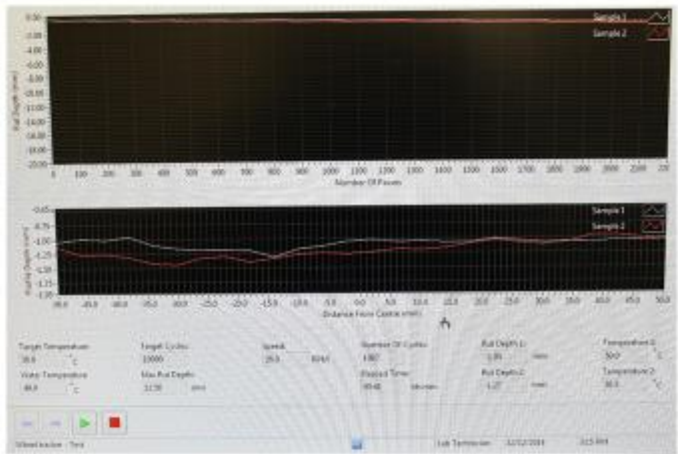
Apparatus – Wheel Pass Counter

- Recorded through the software.
- Allows for rut depth to be expressed as a function of wheel passes.



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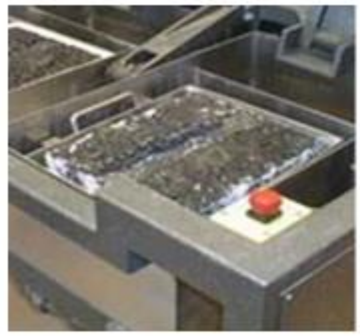
Apparatus – Slab Specimen Mounting System

- Stainless steel tray.
- Restricts movement of the specimen during testing.
- Suspends the specimen and allows to 20 mm of free water on all sides.



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Apparatus – Cylindrical Specimen Mounting System

- Two polyethylene molds or plaster of Paris.
- Mounted in the same stainless steel tray as slab specimens.

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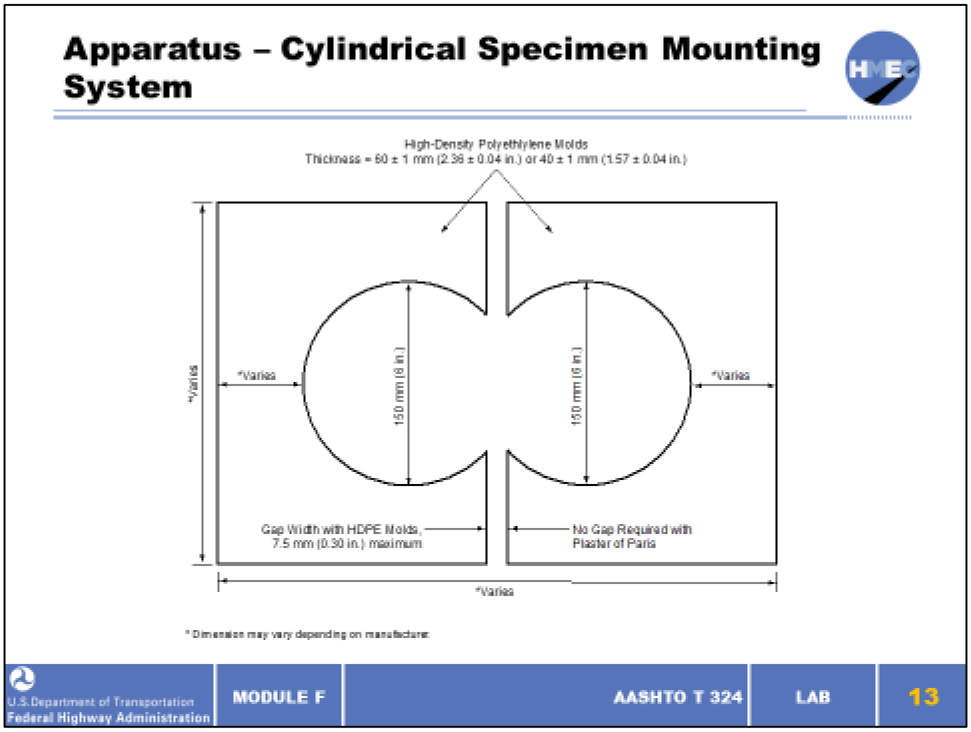
Apparatus – Cylindrical Specimen Mounting System
High-Density Polyethylene Molds
Thickness = 60 ± 1 mm (2.36 ± 0.04 in.) or 40 ± 1 mm (1.57 ± 0.04 in.)
*Varies
*Varies
150 mm (6 in.)
150 mm (6 in.)
*Varies
Gap Width with HDPE Molds, 7.5 mm (0.30 in.) maximum
No Gap Required with Plaster of Paris
*Varies
* Dimension may vary depending on manufacturer
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Apparatus – Cylindrical Specimen Mounting System
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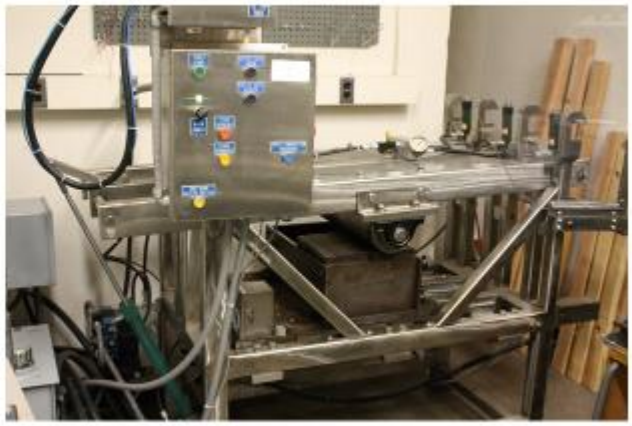
Apparatus – Linear Kneading Compactor

- Steel plates are used to compact specimens to flat, rectangular slabs.



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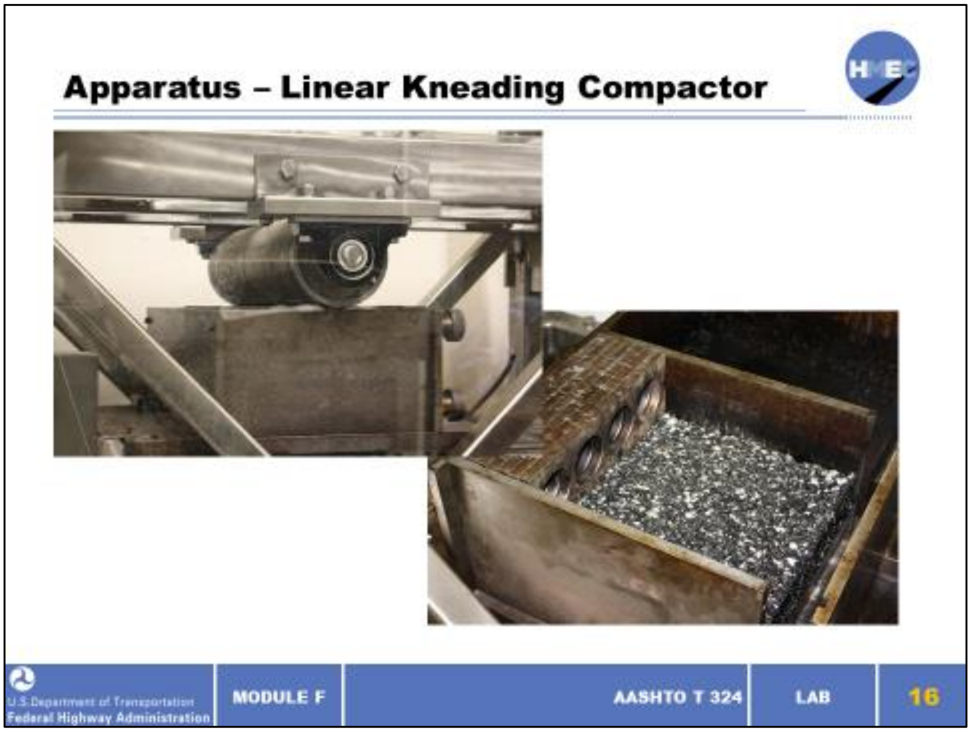
Apparatus – Linear Kneading Compactor
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Apparatus – Superpave Gyratory Compactor
• Molds and compaction device meeting the requirements of AASHTO T 312.
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Specimen Preparation

Specimens may be:

1. Laboratory mixed and laboratory compacted
2. Field mixed and laboratory compacted
3. Field cores

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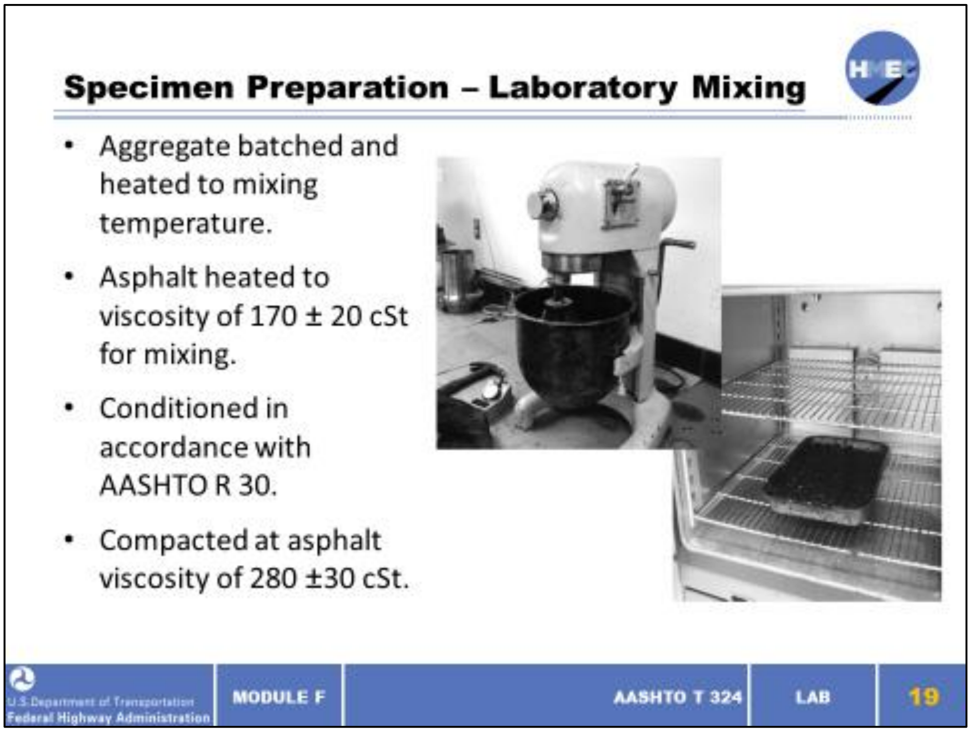
Specimen Preparation – Laboratory Mixing
• Aggregate batched and heated to mixing temperature.
• Asphalt heated to viscosity of 170 ± 20 cSt for mixing.
• Conditioned in accordance with AASHTO R 30.
• Compacted at asphalt viscosity of 280 ±30 cSt.
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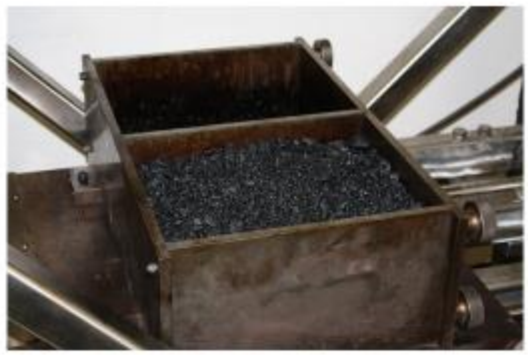
Specimen Preparation – Laboratory Compaction: Linear Kneading Compactor

- Compact specimens that are 320 mm long and 260 mm wide.
- Thickness must be at least twice the thickness of the nominal maximum aggregate size.
- Generally 38 to 100 mm thick.



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Specimen Preparation – Laboratory Compaction: Linear Kneading Compactor
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Specimen Preparation – Laboratory Compaction: Superpave Gyratory Compactor

- Compact specimens that are 150 mm in diameter.
- Specimen height should be at least twice the nominal maximum aggregate size.
- Usually 38 to 100 mm in height.

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Specimen Preparation – Loose Mix From Field

- Sample obtained in accordance with AASHTO T 168.
- Compacted into either slabs or gyratory specimens.

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Specimen Preparation – Field Compacted Slabs or Cores

- Wet-saw cut cores or slabs.
- Cut down to appropriate test size.

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Specimen Preparation – Cutting Gyratory Specimens or Cylindrical Cores

- Saw gyratory specimens along a secant line.
- When joined together there should be a gap no greater than 7.5 mm between the molds.

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Specimen Preparation – Cutting Gyratory Specimens or Cylindrical Cores
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Test Procedure – Air Void Determination

- Recommended target air void content is 7 ± 1.0 percent for laboratory-compacted specimens.
- Filed specimens tests at the air void content at which they are obtained.

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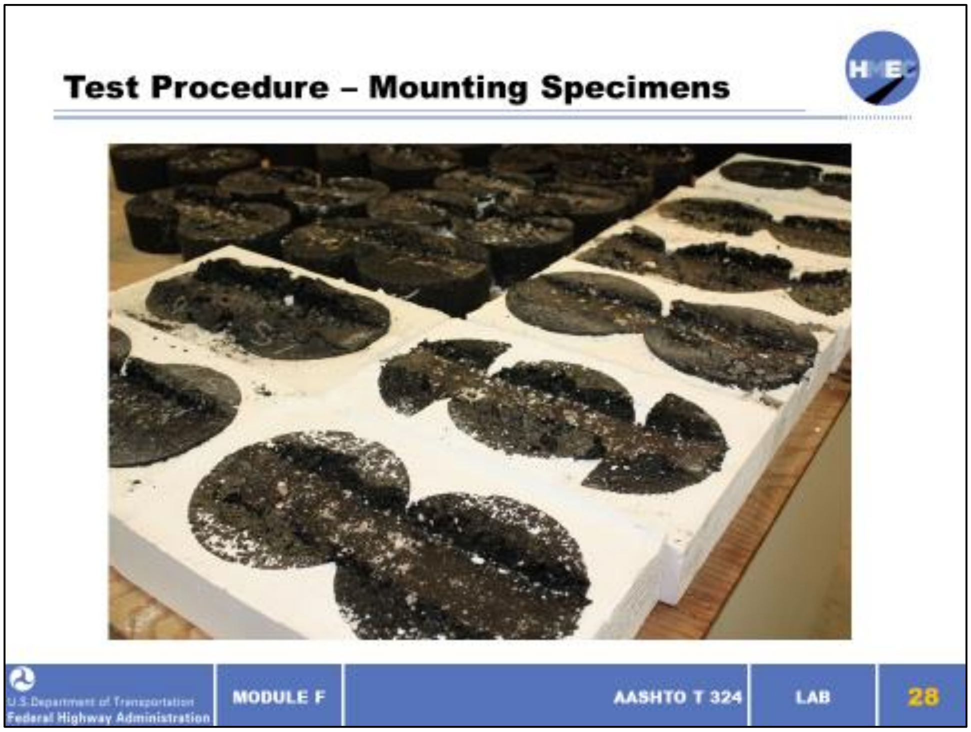
Test Procedure – Mounting Specimens
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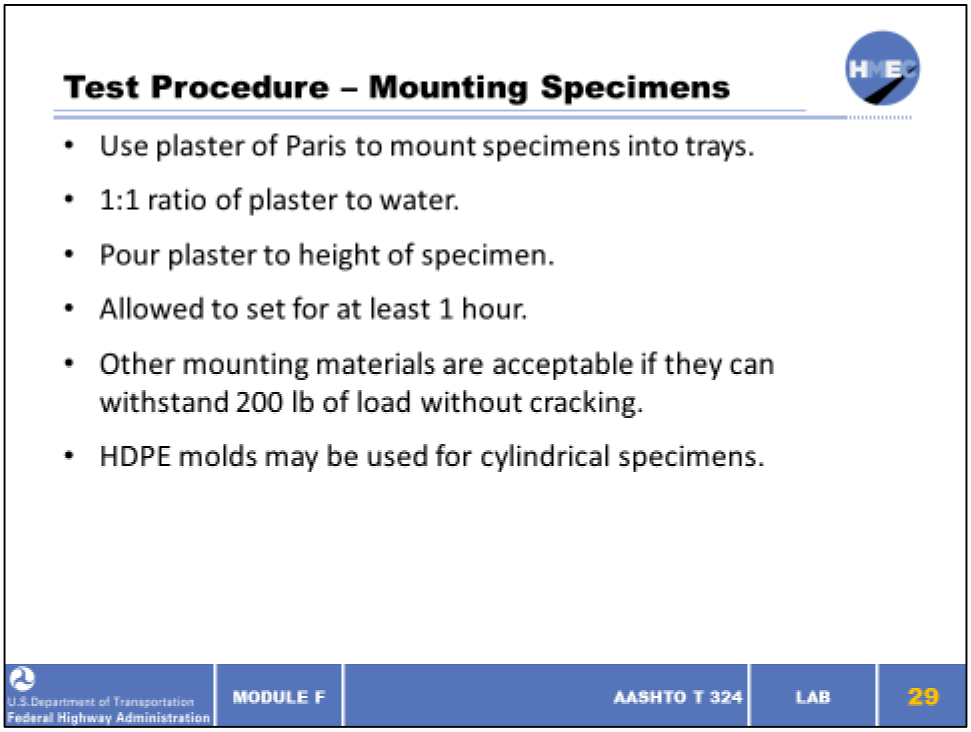
Test Procedure – Mounting Specimens
HMEC
• Use plaster of Paris to mount specimens into trays.
• 1:1 ratio of plaster to water.
• Pour plaster to height of specimen.
• Allowed to set for at least 1 hour.
• Other mounting materials are acceptable if they can withstand 200 lb of load without cracking.
• HDPE molds may be used for cylindrical specimens.
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Test Procedure – Mounting and Initiating Software

- Place mounting trays into the device.
- Software started and pertinent test data is entered.
- Temperature, maximum allowable rut depth, and number of passes selected based on test specifications.
- Set start of test to delay by 30 minutes to precondition the test specimens to test temperature.
- Wheel lowered onto edge of test specimens.
- Most newer devices (made after 1998) perform the remainder of the test automatically after you push the “Start” button.

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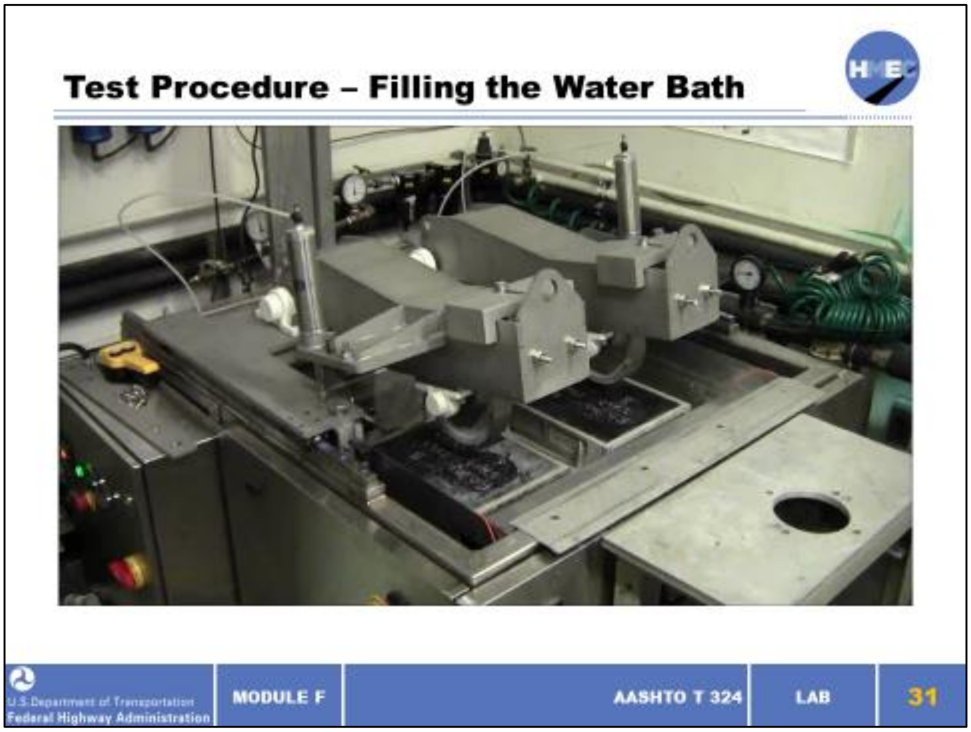
Test Procedure – Filling the Water Bath
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Test Procedure – 30 Minute Conditioning Time
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Test Procedure – Starting the Test
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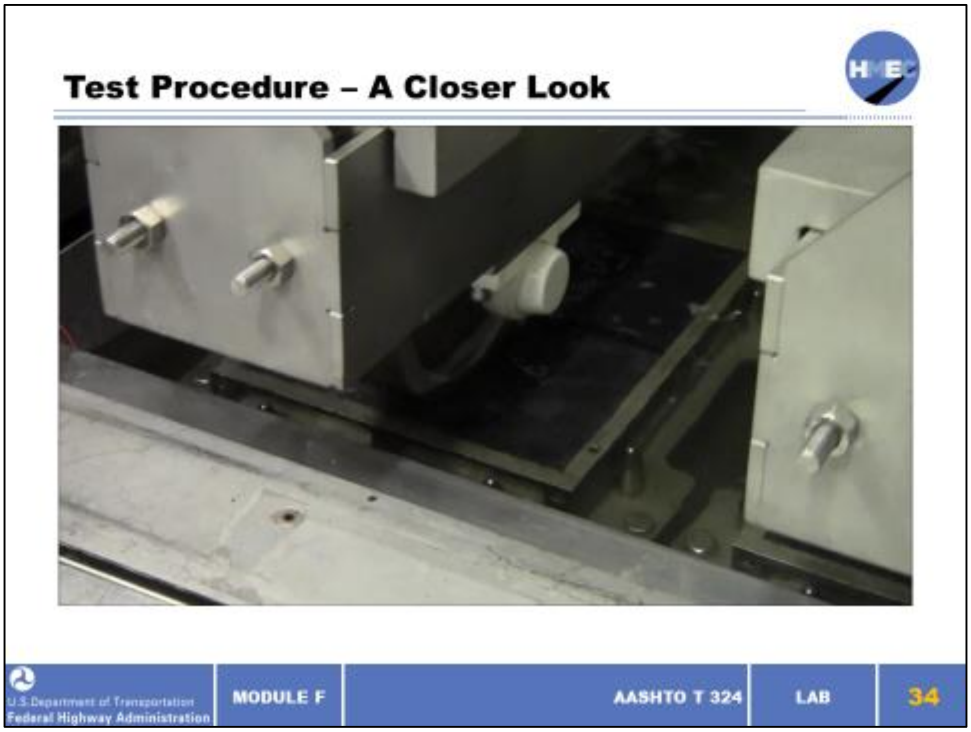
Test Procedure – A Closer Look
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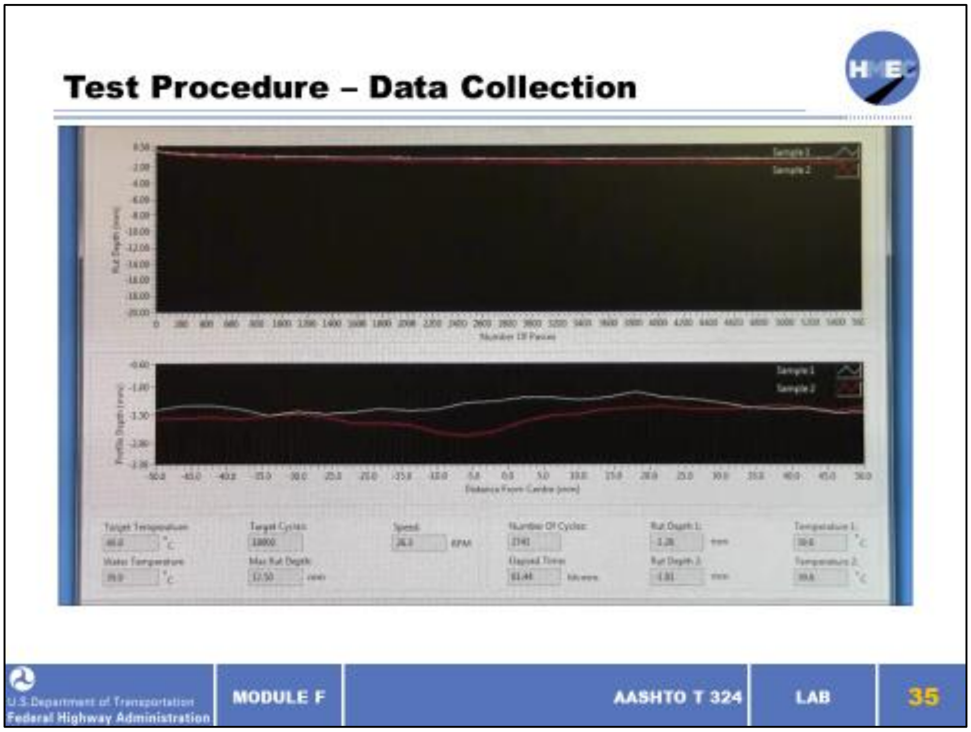
Test Procedure – Data Collection
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Test Procedure – Test Completion

- Testing stopped when 20,000 passes (or other predetermined number of passes) have occurred.

OR

- Maximum rut depth as occurred.

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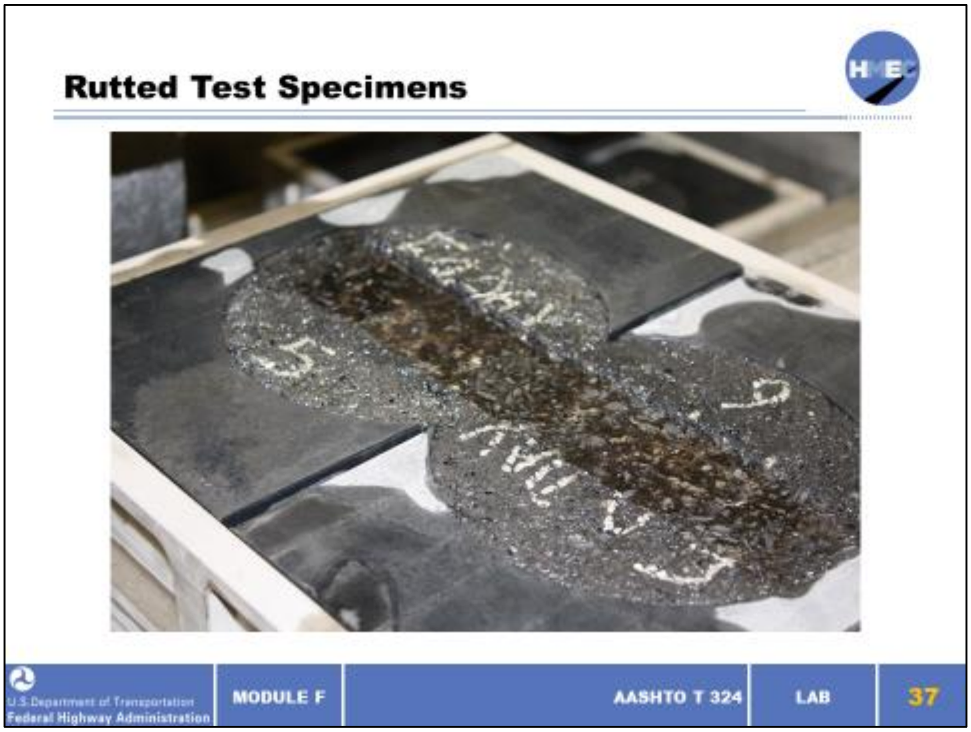
Rutted Test Specimens
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Test Procedure – Test Completion

- Water drained and rutted specimens removed.
- Bath must be cleaned after testing.
- Wet-dry vacuum used to remove particulates from bottom of bath.
- Wheels turned after every test to ensure even wear.

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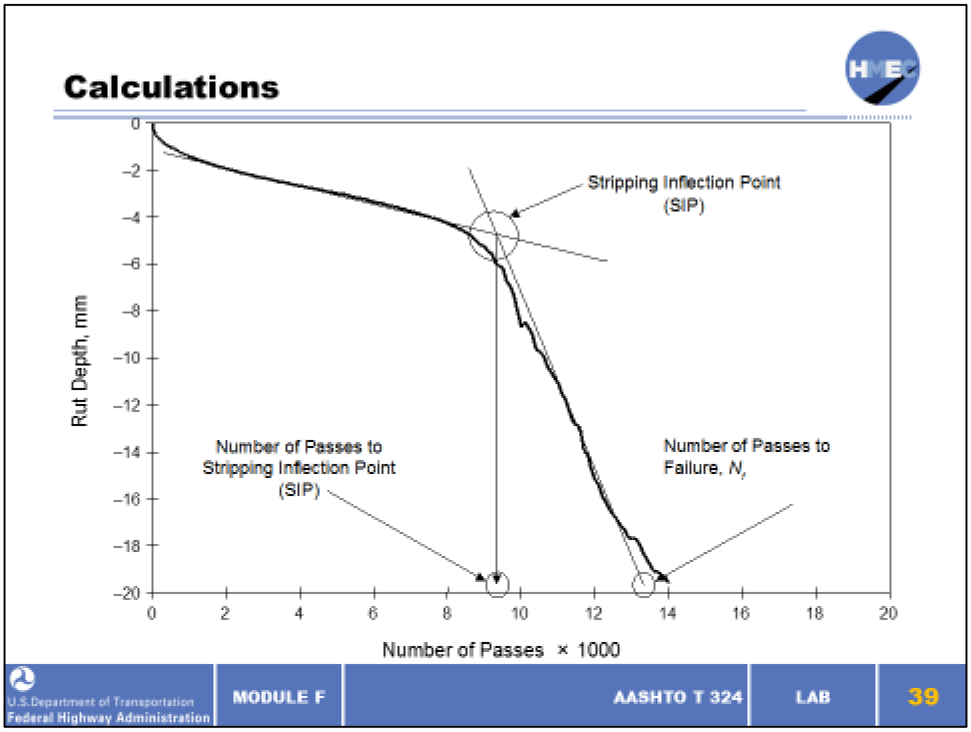
Calculations
Stripping Inflection Point
(SIP)
Rut Depth, mm
0
−2
−4
−6
−8
−10
−12
−14
−16
−18
−20
Number of Passes to
Stripping Inflection Point
(SIP)
Number of Passes to
Failure, N_f
0
2
4
6
8
10
12
14
16
18
20
Number of Passes × 1000
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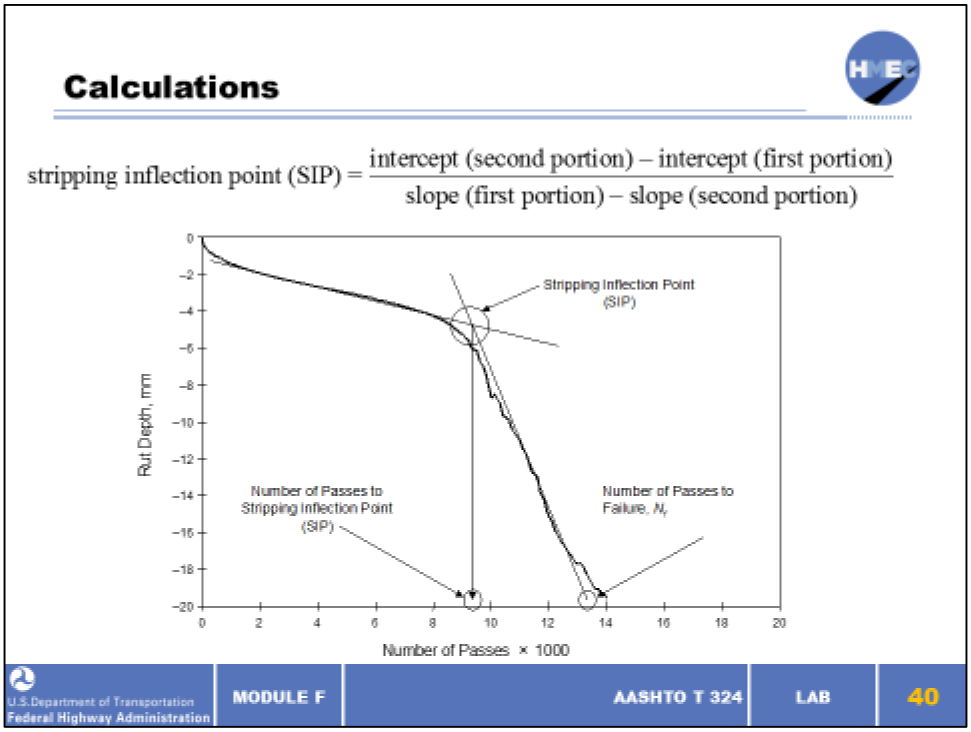
Calculations
HMEC
stripping inflection point (SIP) = [intercept (second portion) – intercept (first portion)] / [slope (first portion) – slope (second portion)]
Stripping Inflection Point (SIP)
Rut Depth, mm
Number of Passes to Stripping Inflection Point (SIP)
Number of Passes to Failure, N_f
Number of Passes × 1000
0
−2
−4
−6
−8
−10
−12
−14
−16
−18
−20
0 2 4 6 8 10 12 14 16 18 20
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Other Performance Tests – Asphalt Pavement Analyzer
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Questions?
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