HMEC

Highway Materials Engineering Course

PARTICIPANT WORKBOOK

LABORATORY MANUAL

Asphalt Binder PG Tests

MODULE

F

U.S.Department of Transportation
Federal Highway Administration

Contents*

Introduction

The performance graded (PG) binder system is part of the Superpave system related specifically to asphalt binder. The system is used for acceptance purposes in the sale and purchase of asphalt binder in accordance with AASHTO M 320, Standard Specification for Performance-Graded Asphalt Binder. This standard specifies physical properties of the material that must be met under certain climatic and aging conditions. The testing involved is related to the expected performance of the material at these conditions.

Terminology

Complex shear modulus (G*) – As described in AASHTO T 315, the ratio calculated by dividing the absolute value of the peak-to-peak shear stress, τ, by the absolute value of the peak-to-peak shear strain, γ, as measured in kilopascals (kPa).

Creep and recovery – As described in AASHTO T 313, a standard rheological test protocol whereby a specimen is subjected to a constant load for a fixed time period and then allowed to recover at a constant zero load for a fixed time period.

Flexural creep – As described in AASHTO T 313, a test in which a simply supported asphalt binder prismatic beam is loaded with a constant load at its midpoint and the deflection of the beam is measured with respect to loading time.

Nonrecoverable creep compliance (Jnr) – As described in AASHTO T 350, the residual strain in a specimen after a creep and recovery cycle divided by the stress applied, kPa-1.

Performance-graded (PG) binder – a performance-based asphalt grading system intended to minimize the potential for rutting, fatigue cracking, and thermal cracking.

Phase angle (δ) – As described in AASHTO T 315, the angle in radians between a sinusoidally applied strain and the resultant sinusoidal stress in a controlled-strain testing mode, or between the applied stress and resultant strain in a controlled-stress mode, reported to the nearest 0.1 degrees.

Relative density – as described in AASHTO T 228, the ratio of the mass of a given volume of material to the mass of the same volume of water at the same temperature.

Steric hardening (molecular association) – a process where associations occur between asphalt binder molecules during storage at ambient temperature. Molecular associations can increase the dynamic shear modulus of asphalt binders. The amount of molecular association is asphalt specific and may be significant even after a few hours of storage.

Viscosity – As described in AASHTO T 316, a liquid's resistance to flow, measured as the ratio between the applied shear stress and the rate of shear, reported in Pascal seconds (Pa·s).

Terminology Related to Test Times

The following terms are used throughout this manual to describe the time it takes to complete the tests and procedures described.

Prep Time – The time that it takes to prepare the material before test procedure can be initiated, including any other practices or test procedures that must be performed in order to properly condition the material for testing.

Time to Perform Procedure – The time that it takes from start to finish to perform the test procedure, including any wait times or conditioning times that are part of the test procedure, but not including any conditioning of the material that is described in other practices or test procedures.

Hands-On Time – The time in which a task or tasks must actively be performed, not including any wait times or conditioning times in which an activity is not physically performed.

Total Time – The total amount of time required to perform the test procedure from start to finish, including prep time, conditioning or wait times, and hands-on time.

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 the safety data sheets (SDSs) for more information on each of these substances.

- Excel Clean HD (a citrus-based cleaner)
- Glycerin-Talc Mixture
- Ethanol

- 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 laboratory.

Note: OSHA's Hazard Communication Standard has been revised to align with the Globally Harmonized System (GHS) of Classification and Labeling of Chemicals. Companies were required by OSHA to begin making the change from using MSDSs to SDSs (Safety Data Sheets) as the standard nomenclature.

Heat

Asphalt binder and ovens will be heated to temperatures of approximately 163°C (325°F). 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.

Guidance on Precision Estimates

Each of the test methods described herein provide single-operator (repeatability) and multilaboratory (reproducibility) precision estimates. The single-operator precision provides an estimate of the expected variation of two tests performed on the same material, by the same operator, using the same equipment, in the same laboratory. The multilaboratory precision provides an estimate of the expected variation of two tests performed on the same material, by different operators, using different equipment, in different laboratories. If the differences between properly performed tests exceeds these values, the testing practices and equipment should be investigated to determine the cause of the variation.

Table 1: Laboratory Procedures and Time Needed to Complete

Standard Designation	**Test Name**	**Total Time**	**Hands-on Time**
AASHTO T 228	Standard Method of Test for Specific Gravity of Semi-Solid Asphalt Materials	2.5 hours	10 minutes
AASHTO T 315	Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)	45 minutes	10 minutes
AASHTO T 48	Standard Method of Test for Flash and Fire Points by Cleveland Open Cup	1.5 hours	15-30 minutes
AASHTO T 316	Standard Method of Test for Viscosity Determination of Asphalt Binder Using Rotational Viscometer	30 minutes – 1 hour	15-45 minutes
AASHTO T 240	Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)	6-8 hours	30 minutes
AASHTO T 350	Standard Method of Test for Multiple Stress Creep Recovery (MSCR) Test of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)	35 minutes	10 minutes
AASHTO R 28	Standard Method of Test for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)	21 hours	30 minutes
AASHTO T 313	Standard Method of Test for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)	3 hours	20 minutes
AASHTO T 314	Standard Method of Test for Determining the Fracture Properties of Asphalt Binder in Direct Tension (DT)	24 hours	60 minutes
AASHTO R 29	Grading or Verifying the Performance Grade (PG) of an Asphalt Binder	N/A	N/A

*The procedures described in this manual are listed in the order in which they appear in AASHTO R 29, Grading or Verifying the Performance Grade (PG) of an Asphalt Binder.

AASHTO T 228, Standard Method of Test for Specific Gravity of Semi-Solid Asphalt Materials

Background Information

The asphalt binder specimen is placed in a calibrated pycnometer, the mass of the pycnometer and specimen is determined, and then the remaining volume in the pycnometer is filled with water. The filled pycnometer is brought to the test temperature and its mass is then determined. The density of the asphalt binder specimen is calculated from its mass and the mass of the water displaced by the specimen.

Significance and Use

Because the specific gravity of asphalt binders changes with temperature, this test is useful in making volume corrections based on temperature. The specific gravity at 15.6°C (60°F) is commonly used when buying/selling asphalt. A typical specific gravity for asphalt binder is around 1.030.

Related Tests, Practices and Specifications

- AASHTO T 40, Sampling Bituminous Materials
- ASTM D4311, Determining Asphalt Volume Correction to a Base Temperature

Timeline for Completion

Prep Time: Approximately 1 hour

Bring the beaker and water bath to test temperature and heat the asphalt binder so it can be poured.

Time to Perform Procedure: 80–90 minutes

Calibrate the pycnometer (if not previously done). Pour the asphalt binder into the pycnometer and allow it to cool at ambient temperature for at least 40 minutes. Determine the mass of the pycnometer and specimen, fill the remaining volume in the pycnometer with water, and bring the filled pycnometer to the test temperature. Determine its mass.

Calculations: 2 minutes

TOTAL TIME: 2.5 hours

Apparatus

- Beaker – 600 mL or larger.
- Water bath with thermometer – The temperature of the water shall be maintained within ± 0.1°C (± 0.2°F) of the test temperature.
- Analytical balance
- Distilled or deionized water
- Glass pycnometer with stopper – capacity of 24 to 30 mL.

Figure 1: Pycnometer and stopper

Apparatus Preparation

1. Boil and cool the distilled or deionized water.
2. Fill the beaker with this water to a level that will allow the top of the pycnometer to be immersed at least 40 mm.
3. Place the beaker in the water bath so that the bottom of the beaker is immersed at least 100 mm and the top of the beaker is above the water level in the bath (Figure 2).
4. Ensure the beaker will not tip over.

Figure 2: Beaker in water bath

Pycnometer Calibration

1. Determine the mass of the pycnometer and stopper (both clean and dry).
2. Fill the pycnometer with water and place the stopper loosely in the top; place pycnometer in the beaker and press the stopper into place.
3. Place the pycnometer in the water bath for at least 30 minutes.
4. Remove from bath and dry the pycnometer and stopper.
   Note: Pycnometer calibration must be done at the test temperature (normally 25.0 ± 0.1°C [77.0 ± 0.2°F]).
5. Determine the mass to the nearest 0.001 g.

Sample Preparation

Asphalt binder samples should be warmed until they are fluid enough to be poured. However, heating times should be minimized and a sample shall never be heated above a temperature of 110°C (230°F) above its expected softening point.

Note: Avoid excessive or vigorous stirring of the asphalt binder sample. Excessive air bubbles in the specimen will affect (decrease) the specific gravity of the asphalt binder.

Procedure

Step 1
Pour asphalt binder into a clean, dry, and warmed calibrated pycnometer until it is about ¾ full (Figure 3).

Figure 3 – Pouring asphalt binder into pycnometer

Step 2
Cool the pycnometer to ambient temperature, but not less than 40 minutes.

Step 3
Determine the mass of the pycnometer, stopper, and specimen to the nearest 0.001 g.

Step 4
Fill the pycnometer (with specimen) with water and loosely place the stopper on the pycnometer.

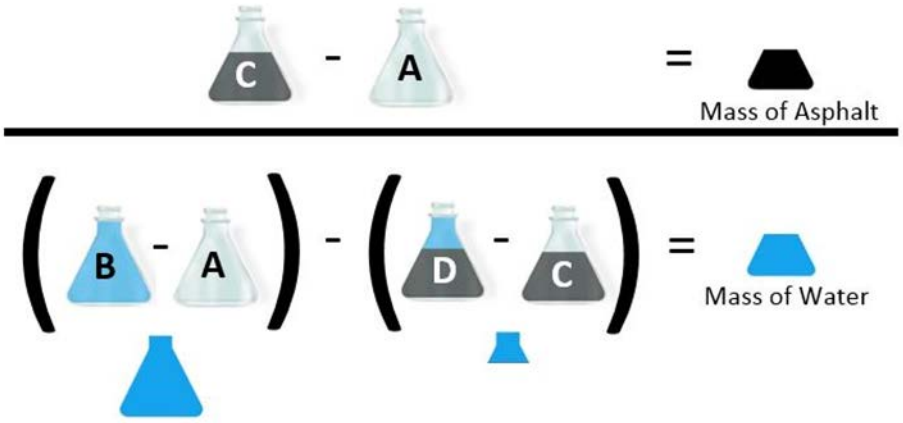
Step 5
Place the pycnometer in the water bath for at least 30 minutes.

Step 6
Remove the pycnometer from the water bath and dry.

Step 7
Determine the mass to the nearest 0.001 g.

Calculations

$$\text{relative density} = \frac{(C - A)}{(B - A) - (D - C)}$$



Where:

A = mass of pycnometer (plus stopper);

B = mass of pycnometer filled with water (plus stopper);

C = mass of pycnometer partially filled with asphalt binder (plus stopper), and

D = mass of pycnometer, asphalt, and water (plus stopper).

Note: Relative density is also described as specific gravity.

$$Density = relative\ density \times W_T$$

Where:

W_T = density of water at the test temperature (see note below)

Note: The density of water from the CRC Handbook of Chemistry and Physics states:

Temperature, °C	Density of Water, kg/m3 (kg/L)
15.6	999.0 (0.9990)
25.0	997.0 (0.9970)

Example Calculations

A = 28.581 g

B = 51.957 g

C = 46.608 g

D = 52.422 g

$$\text{relative density} = (\text{C} - \text{A}) \,/\, [(B - A) - (D - C)]$$

$$\text{relative density} = (46.608 - 28.581) \,/\, [(51.957 - 28.581) - (52.422 - 46.608)] = 1.026$$

$$Density = relative\ density \times W_T = 1.026 \times 997.0 = 1023\ kg/m^3 @\ 25.0°C$$

Common Errors

- The water used in the pycnometer is not freshly boiled (and cooled), distilled, or deionized.

Data Sheet

Asphalt Binder Specific Gravity (AASHTO T 228)	
Mass of Empty Pycnometer, nearest 0.001 g (A)	
Mass of Pycnometer Filled with Water, nearest 0.001 g (B)	
Mass of Pycnometer Partially Filled with Asphalt, nearest 0.001 g (C)	
Mass of Pycnometer Filled with Asphalt and Water, nearest 0.001 g (D)	
Relative Density $= (\mathrm{C} - \mathrm{A}) / [(B - A) - (D - C)]$	
Density = Relative Density X 997.0 kg/m^3 (for tests at 25°C)	

AASHTO T 315, Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

Background Information

A parallel plate geometry is used to test the samples, and the plate diameter is 25 mm for neat and RTFO-conditioned binder, and 8 mm diameter plates for PAV-conditioned binder. During testing, one of the plates is oscillated with respect to the other plate. The complex shear modulus, G*, is calculated by dividing the maximum stress by the maximum strain that occurs during the loading cycle. The phase angle of the material, δ, represents the delay in the material's response to the applied load.

Significance and Use

The Strategic Highway Research Program (SHRP) was established by Congress in 1987 to conduct 5-year $150 million research program to improve the durability and performance of asphalt materials. The final product of the SHRP asphalt research program was a new system referred to as Superpave (SUperior PERforming asphalt PAVEments. The performance-graded (PG) binder suite of tests is a component of the Superpave system. Arguably one of the most important tests in the PG specification, the DSR test, is used to determine the complex shear modulus and phase angle of asphalt at temperatures ranging from 3 to 88°C. In accordance with AASHTO M 320, the test is performed at 10 radians/second. This loading cycle simulates a wheel passing over the pavement surface at 55 mph. The complex shear modulus and phase angle together are used to characterize the binder at high and intermediate temperatures in order to determine the performance grade.

Related Tests, Practices and Specifications

- AASHTO M 320, Standard Specification for Performance-Graded Asphalt Binder
- AASHTO R 28, Standard Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
- AASHTO R 29, Standard Practice for Grading or Verifying the Performance Grade of an Asphalt Binder
- AASHTO T 240, Standard Method of Test for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)

Timeline for Completion

Prep Time: 15 min–24 hours

The sample preparation time is dependent upon whether original, RTFO-conditioned, or PAV-conditioned material is used.

Time to Perform Procedure: 30 minutes

Approximately 10 minutes to prepare the sample, 15 minutes to mount, trim, and condition the sample, and 5 minutes of clean-up.

TOTAL TIME: 30 minutes

Apparatus

Dynamic Shear Rheometer – Consisting of parallel metal plates, an environmental chamber, a loading device, and a control and data acquisition system as described in Section 6 of AASHTO T 315 (Figure 4). The environmental chamber may be either an air bath or a water bath; 25-mm plates are used to test original and RTFO-conditioned material, and 8-mm plates are used to test PAV-conditioned material. The calibration of the loading device and temperature control system must be verified every six months by the use of a standard reference fluid and a reference thermometer, respectively. The procedure for performing these verifications is described in Section 9 of AASHTO T 315.

Figure 4: Dynamic Shear Rheometer

Plate Size: The 8-mm plates are used at the intermediate test temperature because the binder is stiffer at the intermediate temperatures. In addition, the material has been conditioned in the PAV when tested at the intermediate temperature, which also contributes to the stiffness of the binder. In order to reduce the effect of mechanical machine compliance that could result in erroneous data, a smaller plate has to be used at the intermediate temperature.

Specimen Mold (Optional) – A silicone mold may be used to form test specimens to mount into the DSR test apparatus. Alternatively, the sample may be transferred to the test plates through

a direct-pour method, which is described in the test procedure section of this lab manual. A typical specimen mold is shown in Figure 5.

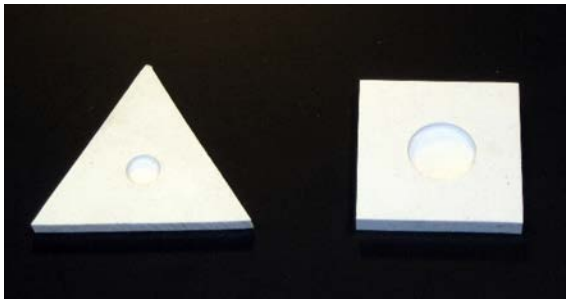


Figure 5: Silicone specimen molds

Cleaning Materials – Cloths, swabs, paper towels, or other materials for cleaning the test plates. A solvent such as mineral oil, citrus-based cleaner, mineral cleaner, or toluene is used to clean the asphalt off of the test plates. Acetone is needed to remove the solvent residue from the plates.

Preparation of DSR

Step 1

Prepare the DSR in accordance with the manufacturer's instructions. The process for each make, model, and manufacturer will vary.

Step 2

Ensure that the plates have been thoroughly cleaned and are free from scratches and jagged edges. Install the plates into the rheometer.

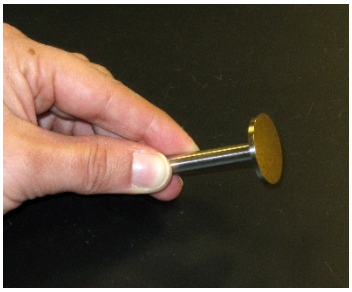


Figure 6: Inspecting the test plates

Step 3

Select the test temperature in accordance with AASHTO M 320 and AASHTO R 29. Set the DSR temperature control system to the appropriate temperature and allow the temperature to stabilize to within ±0.1°C. If the sample is to be tested at multiple temperatures, set the temperature for the mid-point of the range of temperatures to be used.

Step 4

Determine the zero gap level of the rheometer:

If the rheometer does not have a normal force transducer (rare) – Manually spin the top plate while bringing the plate down so that it makes contact with the bottom plate. The zero gap level has been reached when the top plate stops spinning.

If the rheometer does have a normal force transducer (common) – Close the gap between the two plates. When the plates come in contact, set the normal force at zero. On most modern DSRs, this process is automated and is performed through the computerized control system accompanying the device.

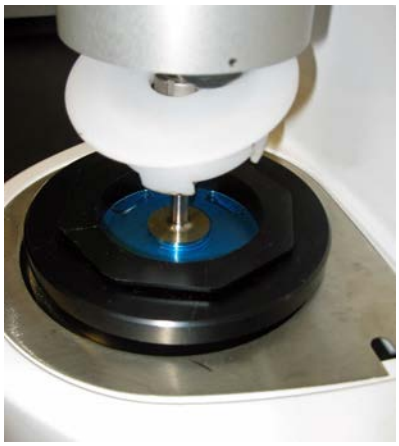


Figure 7: Setting the gap

Step 5

Preheat the plates:

Adjust the plates in position to approximately the testing gap (usually 1 mm for 25-mm plates and 2 mm for 8-mm plates).

To preheat 25-mm plates, adjust the temperature to the lowest test temperature to be used. To preheat the 8-mm plates, adjust the temperature to between 34 and 46°

Preheating 8-mm Plates: The 8-mm plates are preheated to a temperature that is higher than the test temperature. This is done in order to ensure proper adhesion of the asphalt binder to the test plates.

Sample Preparation

Step 1
Heat the asphalt binder until it is sufficiently fluid to pour. Samples should be either original binder, or binder aged in the rolling thin-film oven (RTFO) in accordance with AASHTO T 240 and/or the pressurized aging vessel (PAV) in accordance with AASHTO R 28.

Step 2
Transfer the sample to the test plates by one of the following methods:

Pouring – The pouring method can only be used for rheometers that are designed to allow the plates to be removed without affecting the zero gap setting. Remove the top plate, and pour the asphalt binder onto the center of the plate until it covers all but a 2-mm strip of the plate at the perimeter. Allow the material to stiffen, and then replace the top plate into the rheometer.

Direct Transfer – Transfer hot asphalt binder to one of the plates by use of a glass or metal rod.

Silicone Mold – Pour the asphalt into a silicone mold and allow it to cool at room temperature to form a small pellet. Cover the mold while the sample is cooling to prevent contamination. Once cooled, press the material onto either the top or bottom plate and remove the rubber mold.

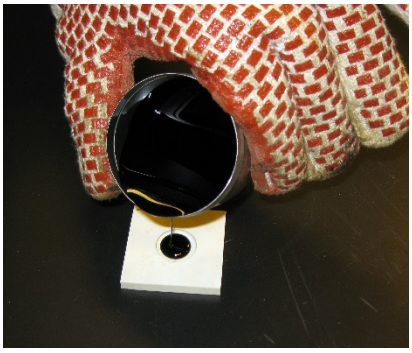


Figure 8: Pouring asphalt in silicone mold

Step 3
Move the test plates together to a distance that is equal to 1.05 mm for 25-mm plates or 2.10 mm for 8-mm plates.

Step 4
Trim the excess binder from the specimen by moving a heated trimming tool around the edges of plates. The asphalt binder should be flush with the edge of outer diameter of the plates.

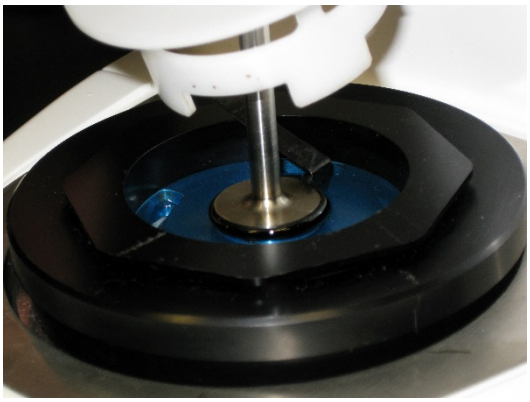


Figure 9: Trimming the DSR test specimen

The Importance of Trimming: The importance of properly trimming the test specimen cannot be overstated. The diameter of the test specimen is factored four times into the calculations and test results, and poor trimming practice can lead to significant errors in the reported data.

Step 5
Reduce the distance between the plates to the testing gap (1.00 mm for 25-mm plates or 2.00 mm for 8-mm plates). This creates a bulge in the specimen which helps to reduce edge effects and trimming error.

Step 6
Close the environmental chamber so that the sample can be adjusted to the test temperature.

Procedure

Step 1
Bring the specimen to within ±0.1°C of the test temperature.

Step 2
Allow the specimen to remain at the test temperature for 10 minutes before starting the test. Most modern rheometers are equipped with software that automates this step in the test procedure.

Step 3
The test may be performed in either stress-controlled or strain-controlled mode. Most modern rheometers are equipped with software that automatically selects the correct stress or strain value to be used for the test in accordance with AASHTO M 320.

Step 4

The following steps are performed automatically by the DSR once the test temperature has been maintained for 10 minutes:

1. The specimen is conditioned by applying 10 oscillatory cycles. The purpose of these conditioning cycles is to remove any steric hardening from the sample before test results are collected.
2. A second set of 10 cycles are performed and the data is collected by the rheometer's data acquisition system.
3. G* and δ are automatically calculated and reported by the DSR software.

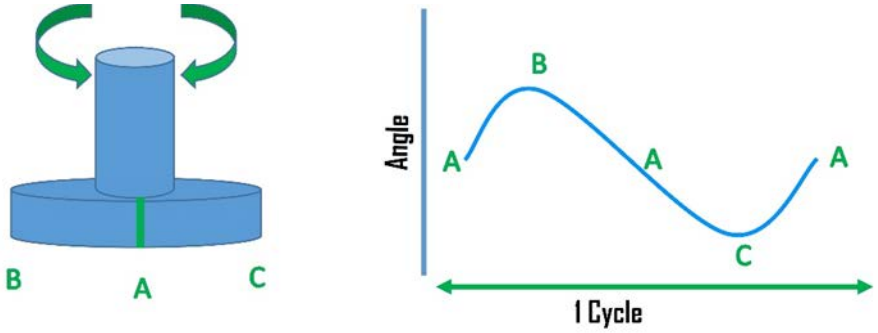


Figure 10: Illustration of an oscillation cycle

Example Report

The DSR software typically generates a report with the information shown in Table 2 and Table 3. Note that for original and RTFO-conditioned binder, the final reported value is calculated as G*/(sinδ). For PAV-conditioned binder, the final reported value is calculates as G*(sinδ).

Table 2: Example Report, DSR Test on Original Binder

Test Information	**Result**				
Sample Number	AJB123 - Original				
Test Plate Diameter (nearest 0.1 mm)	25.0 mm				
Test Gap (nearest 1 μm)	1.000 mm				
Test Temperatures (nearest 0.1°C)	64.0°C				
Test Frequency, rad/s	10 rad/s				
Strain Amplitude, if strain controlled (nearest 0.01 percent)	12.32%				
Torque, if stress controlled (nearest mN·m)	N/A – strain controlled				
Complex Modulus, G*, for 10 cycles (kPa to three significant figures)	1.14	1.13	1.14	1.15	1.16
	1.12	1.14	1.14	1.13	1.14
Phase angle, δ, for 10 cycles (nearest 0.1 degrees)	58.2	58.3	58.3	58.1	58.3
	58.2	58.3	58.4	58.3	58.2
G*/(sinδ) (nearest 0.01 kPa)	1.34 kPa				

Table 3: Example Report, PAV-Conditioned Binder

Test Information	**Result**				
Sample Number	AJB123 - PAV				
Test Plate Diameter (nearest 0.1 mm)	8.0 mm				
Test Gap (nearest 1 μm)	2.000 mm				
Test Temperatures (nearest 0.1°C)	22.0°C				
Test Frequency, rad/s	10 rad/s				
Strain Amplitude, if strain controlled (nearest 0.01 percent)	0.98%				
Torque, if stress controlled (nearest mN·m)	N/A – strain controlled				
Complex Modulus, G*, for 10 cycles (kPa to three significant figures)	1165	1164	1163	1165	1162
	1164	1165	1163	1162	1163
Phase angle, δ, for 10 cycles (nearest 0.1 degrees)	50.1	50.2	50.0	50.1	50.2
	50.1	50.1	50.1	50.2	50.1
G*(sinδ) (nearest 0.01 kPa)	881kPa				

Interpreting and Utilizing the Test Results

The results of AASHTO T 315 are commonly used in conjunction with AASHTO M 320 and AASHTO R 29 to determine or verify the performance grade of the asphalt binder.

Common Errors

The most commonly-observed errors made by technicians performing AASHTO T 315 are as follows:

- Reference equipment used to verify the calibration of the temperature measurement system do not meet the requirements of the standard.
- Verification of the calibration of the temperature measurement system and the torque transducer have not been performed at the proper interval.
- The sample was not trimmed so that the material was flush with the outside edge of the plates.
- When performing the test using PAV-conditioned material (8-mm plates), the gap was determined at the mounting temperature instead of the test temperature.

- When performing the test using PAV-conditioned material (8-mm plates), the sample was not mounted at a temperature between 34 and 46°C.

Data Sheet

DSR Data for Verifying Performance Grade			
Sample Name:			
	Original Binder	**RTFO-Conditioned Binder**	**PAV-Conditioned Binder**
Average Complex Modulus, G^*			
Average Phase Angle, δ			
$G^*/(\sin\delta)$			----------
$G^*(\sin\delta)$	----------	----------	

AASHTO T 48, Standard Method of Test for Flash and Fire Points by Cleveland Open Cup

Background Information

Flash point testing was developed in the 19th century as a method of determining the quality of fuels and lubricants. Originally simple gas or electrically-heated instruments were only available, but since the mid-1960s automatic systems have been available and have become popular. The flash point is the lowest temperature, corrected to a barometric pressure of 101.3 kPa (760 mm Hg), at which application of an ignition source (small flame) causes the vapors of a specimen to ignite under specified test conditions. A test cup containing approximately 70 mL of asphalt binder is heated, rapidly at first and then at a slower rate as the expected flash point is approached. A small flame is passed over the cup at every 2°C (5°F) rise in temperature until the application of the flame causes the vapors of the specimen to ignite.

Significance and Use

The flash point is used in shipping and safety regulations to define flammable and combustible materials. AASHTO specifications M 320 and MP 19 require that the flash point of asphalt binder be at least 230°C (446°F).

Related Tests, Practices and Specifications

- AASHTO M 320, Specification for Performance-Graded Asphalt Binder
- AASHTO MP 19, Specification for Performance-Graded Asphalt Binder Using Multiple Stress Creep Recovery (MSCR) Test
- AASHTO T 40, Sampling Bituminous Materials

Timeline for Completion

Prep Time: Approximately 1 hour

The test cup must be cleaned and the asphalt binder heated so it can be poured.

Time to Perform Procedure: 15–30 minutes

The asphalt binder in the test cup is heated, rapidly at first, and then at a slower rate as the expected flash point is approached. A small flame is passed over the cup at every 2°C (5°F) rise in temperature until the flash point is reached.

Calculations: 1 minute (if needed)

No calculations are required unless the barometric pressure differs from 101.3 kPa (760 mm Hg).

TOTAL TIME: 1.5 hours

Apparatus

Cleveland Open Cup Apparatus – This consists of the test cup, heating plate, test flame applicator, heater, and thermometer. The apparatus may be automated or manually-operated (as shown in Figure 11).

Figure 11: Cleveland open cup apparatus

Sample Preparation

Asphalt binder samples should be warmed until they are fluid enough to be poured. However, heating times should be minimized and a sample shall never be heated above a temperature of 56°C (100°F) below its expected flash point.

Note: Erroneously high flash points may be obtained if precautions are not taken to avoid the loss of volatile material. Therefore, when possible, the flash point should be the first test performed on a sample and the sample should be stored at a low temperature.

The apparatus should be on a level and steady surface. Tests shall be performed in a draft-free room or compartment.

Procedure

Step 1
Determine what the expected flash point temperature will be. If there is no previous data, then use 300°C (572°F) as the expected flash point temperature.

Note: Most asphalt binders flash between 300 (572°F) and 340°C (644°F); however, some can flash as low as 260°C (500°F).

Step 2
As the sample heats, the initial rate of temperature rise should be 10 to 20°C (18 to 36°F) per minute.

Step 3
When the test temperature reaches approximately 56°C (100°F) below the expected flash point, adjust the heat if necessary so the rate of temperature rise will be 4 to 7°C (7 to 13°F) per minute during the last 28°C (50°F) before the flash.

Step 4
When the test temperature reaches 28°C (50°F) before the expected flash point, apply the test flame.

Step 5
After the initial application, the test flame should be applied at every 2°C (5°F) interval until the flash point is reached.

Step 6
If a skin forms on the sample surface before the flash point is reached, carefully move it aside with a glass rod or paper clip (Figure 12).

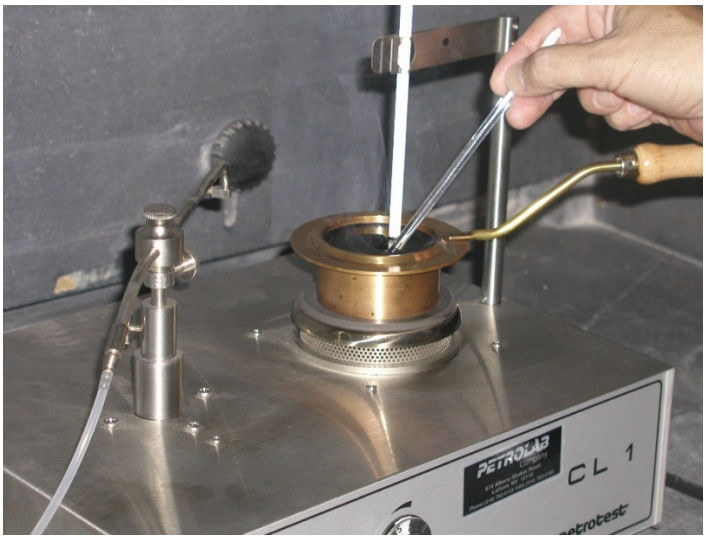


Figure 12: Removing skin from sample surface

Step 7

The flash point is reached when a flame appears on the surface of the specimen and propagates itself over the surface. Record, as the observed flash point, the temperature on the thermometer when the flash occurred, rounded to the nearest 1°C (2°F).

Note: The application of the flame can cause a blue halo or an enlarged flame. This is not a flash point (although it is an indication that the flash point is close) and should be ignored.

Calculations

If the barometric pressure differs from 101.3 kPa (760 mm Hg), correct the flash point as follows:

$$Corrected\ flash\ point\ = C + 0.25\ (101.3 - K)$$

$$Corrected\ flash\ point\ = F\ + 0.06\ (760 - P)$$

$$Corrected\ flash\ point\ = C + 0.033\ (760 - P)$$

where:

C = observed flash point, °C

F = observed flash point, °F

P = ambient barometric pressure, mm Hg

K = ambient barometric pressure, kPa

Note: The barometric pressure used in these calculations is the ambient pressure for the laboratory at the time of test. Many aneroid barometers, such as those used at weather stations and airports, are pre-corrected to give sea level readings and would not give the correct reading for this test.

Example Calculations

Assume the observed flash point in a laboratory in Denver was 280°C. The barometric pressure at the time of the test was 620 mm Hg.

$$Corrected\ flash\ point\ = C + 0.033\ (760 - 620)\ = 284.62°C$$

This corrected flash point would be rounded to 285°C.

Note: The barometric pressure would have to differ from 760 mm Hg by at least 15 mm Hg before the flash point would need to be corrected by even 1°C.

Common Errors

- By far the most common error we see is deviation from the rate of temperature rise (10 to 20°C [18 to 36°F] per minute initially, 4 to 7°C [7 to 13°F] during the latter portion of the test.) This can be difficult to maintain. A rate of temperature rise slower than prescribed could lead to an erroneously high flash point, and a rate of temperature rise faster than prescribed could lead to an erroneously low flash point.

Data Sheet

Cleveland Open Cup Flash Point Test Results	
Sample Number	
Observed Flash Point	
Barometric Pressure	
Corrected Flash Point (if necessary)	

AASHTO T 316, Standard Method of Test for Viscosity Determination of Asphalt Binder Using Rotational Viscometer

Background

The rotational viscometer was adopted for asphalt testing as a result of the Strategic Highway Research Program (SHRP) in 1992. A rotational viscometer is used to measure the viscosity of asphalt binder by shearing the material at a constant rate of strain and at a constant temperature.

Significance and Use

Evaluation of temperature and viscosity relationships allow suppliers and purchasers to determine the minimum temperatures necessary for transporting an asphalt binder while maintaining the fluidity to pump the binder from its containing vessel. The rotational viscometer is also used to select mixing and compaction temperatures for mix design.

Related Tests, Practices and Specifications

- AASHTO M 320, Specification for Performance-Graded Asphalt Binder
- AASHTO R 29, Grading or Verifying the Performance Grade (PG) of an Asphalt Binder
- AASHTO T 40, Sampling Bituminous Materials

Timeline for Completion

Prep Time: 15 minutes

The sample chamber, sample holder, and spindle must be preheated to the test temperature. A small quantity of asphalt binder, usually less than 10.5 g, must be heated until it can be poured.

Time to Perform Procedure: 15–45 minutes

The asphalt is poured into the sample chamber, the sample chamber is loaded into the thermosel, and the spindle is lowered into the sample. The thermosel must recover to test temperature within 30 minutes. The sample must be maintained at test temperature for a minimum of 10 minutes. The spindle rotations are started during this 10-minute equilibration. After equilibration, three readings are obtained from the machine at 1-minute intervals.

Calculations: 1 minute

The three testing results are obtained from a direct digital read out on most models and then averaged.

TOTAL TIME: 30 minutes–1 hour

Apparatus

Rotational Viscometer – (Figure 13) Having a torque transducer and thermosel capable of measuring torque and maintaining test temperatures to 1.0°C.

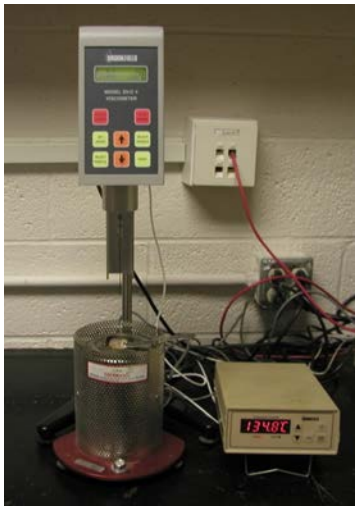


Figure 13: A common rotational viscometer

Oven – An oven for preheating the sample, chamber, and spindle to test temperature.

Balance – A balance for determining the mass of the asphalt binder specimen.

Sample Preparation

The rotational viscometer and temperature controller should be turned on and set to test temperature (typically 135°C) so the thermosel can preheat. The sample holder, chamber, and spindle should also be preheated to test temperature. Commonly, an oven is used to preheat each item; however, the chamber and spindle can be brought to test temperature in the thermosel. The levelness of the both the viscometer and thermosel should be verified prior to the start of the test. Both are commonly equipped with a bubble level.

Note: Often, preheating the sample holder is overlooked. Preheating the sample holder allows it to act as a heat sink while the sample is weighed, which prevents cooling and reduces the time it takes for the sample chamber and thermosel to recover to test temperature.

Procedure

Step 1

Place the sample chamber into the sample holder and tare them both on a balance. Pour the required amount of asphalt binder (Figure 14) into the sample chamber. The sample mass is based on the size of the spindle being used for testing. The manufacturer's instructions give the sample mass for each spindle.

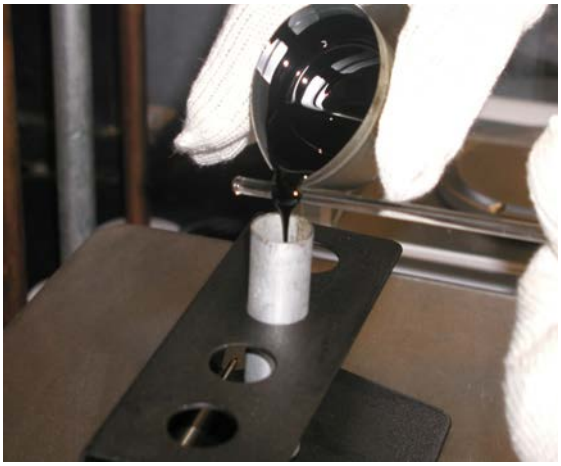


Figure 14: Filling the sample chamber

Step 2

Insert the sample chamber into the thermosel (Figure 15) and lower the spindle from the viscometer into the sample. The top conical portion of the spindle should be completely immersed in the asphalt. The thermosel, sample chamber, and asphalt binder sample must recover to test temperature within 30 minutes, and must be kept at test temperature for equilibration for a minimum of 10 minutes.

Figure 15: Inserting the sample chamber into the thermosel

Step 3
During the 10-minute equilibration, the viscometer should be set to 20 rpm and the motor should be turned on.

Step 4
After the 10-minute equilibration and when the viscosity readings have stabilized, take three viscosity measurements at 1-minute intervals.

Note: The viscosity of the material is reported as torque. The binder adhering to the sides of the chamber is stationary and the binder adhering to the sides of the spindle is revolving. As these layers of binder move concentric to each other, the bonds between the molecules are broken and regained continuously. The viscometer measures this bond energy as resistance to shear, the definition of viscosity, and reports it as torque.

Step 5
For accuracy, the manufacturer provides an operable torque range, usually between 2 and 98%. It may be necessary to increase the RPMs or restart the test with a different spindle size to achieve this range.

Calculations

Take the average of the three readings. Most machines give the torque value in centipoise (cP); however, the viscosity of asphalt is generally reported in Pascal seconds (Pa·s). To convert from cP to Pa·s, move the decimal three places to the left.

Reporting and Interpreting the Test Results

The test results are reported as the average Pascal seconds (Pa·s) and the test temperature should be recorded to the nearest 0.1°C.

When determining the mixing and compaction temperatures for an asphalt binder sample, the test is conducted at 135°C and 165°C. These two points are plotted on a graph having viscosity in Pascal seconds on the logarithmic Y axis and Temperature in °C on the standard X axis (Figure 16:). The mixing range and compaction temperature ranges can then be established from the plotted line by observing the temperature at which the asphalt binder has the correct viscosity range for mixing and compaction requirements.

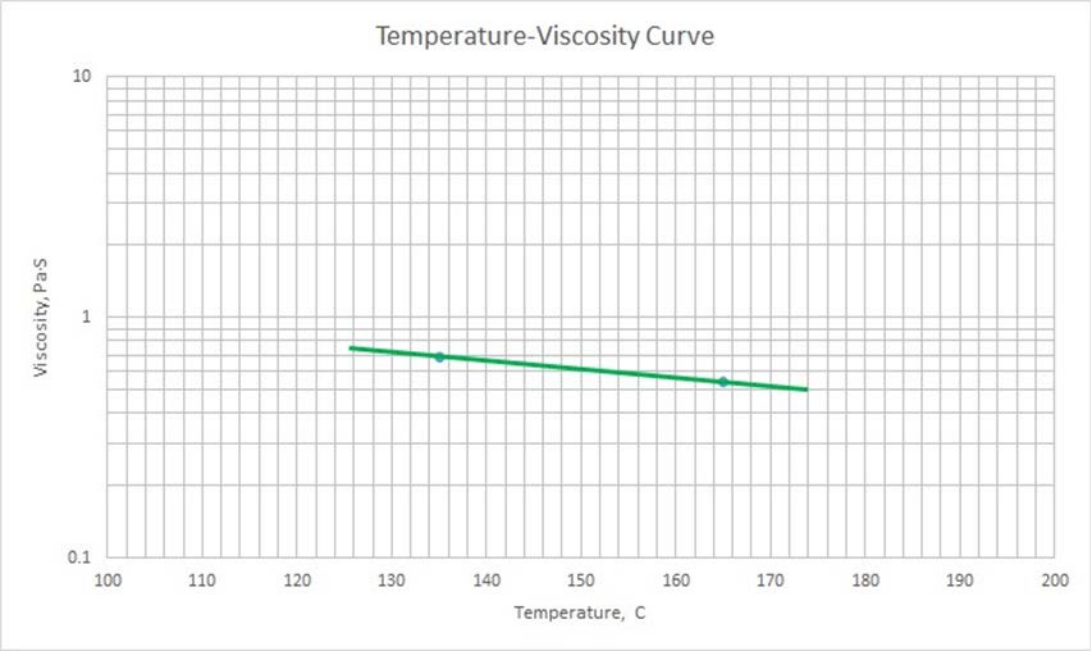


Figure 16: Temperature-Viscosity Curve

Common Errors

- Not heating the sample holder.
- Using a bent spindle wire link.
- Not properly leveling the machine.
- Not recognizing that the machine is not functioning in the proper torque range.

Data Sheet

Rotational Viscometer Test Results – 135°C			
Viscosity Measurements, taken 1 minute apart, Pa·s			
Average Viscosity for the 3 readings, Pa·s			

AASHTO T 240, Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)

Background Information

The rolling-thin film oven was adopted for asphalt testing as a result of the Strategic Highway Research Program (SHRP) in 1992. It is an improvement on a historical test procedure that was used in previous asphalt grading systems, the Thin-Film Oven Test. This test is used to measure the effect of heat and air on a moving film of asphalt binder. The residue from this procedure is used for additional testing, and the mass change that is observed before and after the conditioning process provides an estimate of the loss of volatiles.

Significance and Use

The rolling thin-film oven (RTFO) is used in conjunction with AASHTO M 320 and AASHTO R 29 to determine or verify the performance grade (PG) of an asphalt binder. The residue from the RTFO is tested in the DSR (AASHTO T 315) and undergoes long-term conditioning in accordance with AASHTO R 28. The RTFO conditioning process simulates the condition of the asphalt binder immediately after the pavement is constructed.

Related Tests, Practices and Specifications

- AASHTO M 320, Performance-Graded Asphalt Binder
- AASHTO R 28, Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
- AASHTO R 29, Grading or Verifying the Performance Grade (PG) of an Asphalt Binder
- AASHTO T 315, Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

Timeline for Completion

Prep Time: 2 hours

Preheat oven to specified temperatures.

Time to Perform Procedure: 4–6 hours

Pour liquid asphalt into bottles allow them to cool for 60–180 minutes. Samples are then placed into the RTFO for an 85-minute conditioning period. The bottles are removed from the oven and the material is scraped into one container. Two bottles, which are used for the mass loss determination are allowed to cool for 60–180 minutes before the mass determination.

Calculations: 5 minutes

Determine the mass change.

TOTAL TIME: 6–8 hours

Apparatus

Rolling Thin-Film Oven – A convection oven equipped with a rotating carriage, circulating fan, air jet, and flow meter, as shown in Figure 17.

Figure 17: Rolling thin-film oven

Thermometer – An ASTM 13C (13F) accurate to 0.2˚C (0.5˚F) or equivalent digital temperature measuring device. The thermometer must be positioned internally so that the end of the thermometer bulb (or digital sensor) is within 25 mm (1 in.) of an imaginary line drawn from the center of the rotating axis of the carriage pin.

Containers – A minimum of two glass jars as shown in Figure 18.

Figure 18: Glass container

Balance – With readability of 0.001 g or better for measuring mass loss.

Cooling Rack – A wire or sheet metal cooling rack that allows the samples to cool in a horizontal position.

Scraping Tool – A heat resistant spatula or metal scraper capable of being inserted into the glass containers and removing liquid asphalt.

Equipment Preparation

Preheat the RTFO for a minimum of 2 hours prior to testing with the fan on and the door closed.

Figure 19: Preheating oven

Sample Preparation

Step 1

Select clean sample containers to prepare for testing. Determine and record the mass of at least two of the sample containers for use in determining mass change.

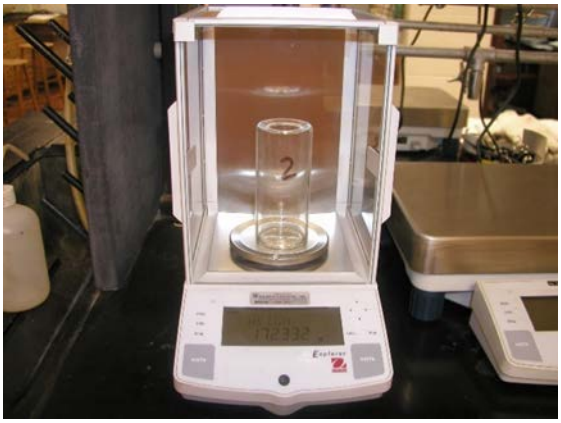


Figure 20: Determining mass of empty sample containers

Step 2

Loosely cover the sample container and heat the asphalt binder in an oven not exceeding 163˚C (325˚F). Thoroughly stir the sample without incorporating additional air bubbles.

Handling Mass Change Bottles: Using gloves or tongs to handle the bottles will help maintain consistency with the mass of the bottles used for determining mass change.

Step 3

Pour 35 ± 0.5 g of the sample into each of the containers. Immediately after pouring, tilt the jar to the horizontal position and slowly rotate 360˚ along the longest axis to precoat the cylindrical surface.

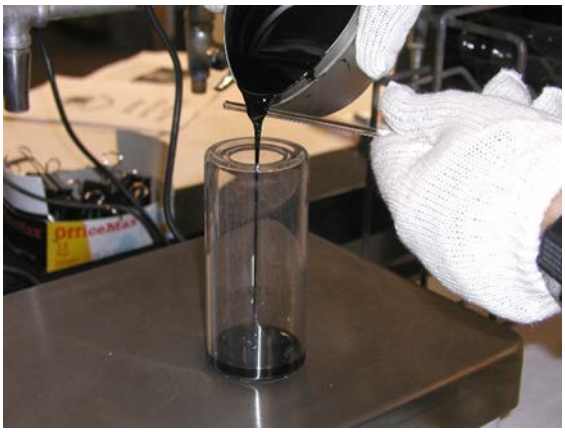


Figure 21: Pouring 35 ± 0.5 g of binder into each container

Step 4

Place the containers on the cooling rack in a draft-free location, away from other ovens or heat sources. Allow the bottles to cool undisturbed on the cooling rack for 60 to 180 minutes as shown in Figure 22.

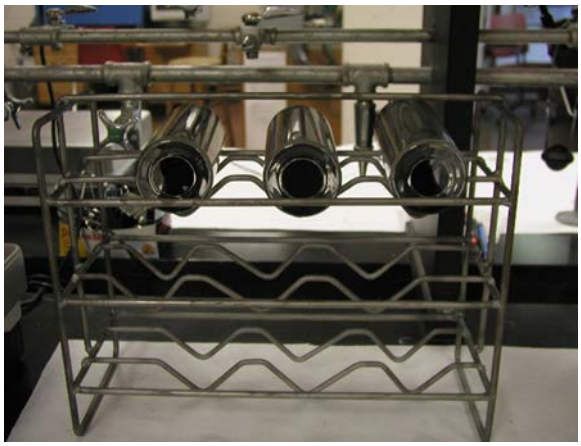


Figure 22: Containers cooling on sample rack

Step 5

After the cooling period, determine the mass of the bottles that are being used for the mass change determination.

Conditioning Procedure

Step 1

Carefully but quickly arrange the bottles in the carriage so that it is balanced. If fewer than 8 bottles are being used, empty bottles should be used to fill the unfilled positions.

Figure 23: Placing samples in rotating carriage

Step 2

Immediately close the door and allow the samples to condition for 85 minutes. The fan should be on and the carriage rotating during the entire conditioning time.

Step 3

Monitor the oven for 10 minutes after closing the door and starting the sample rotation.

The test temperature of 163.0 ± 1.0˚C (325 ± 1.8˚F) shall be achieved within 10 minutes of closing the door. If the oven does not reach the required temperature within the allowable time frame, the test shall be discontinued.

Step 4

After 85 minutes of conditioning, remove the mass change bottles first. Use clean gloves or tongs to avoid any contamination from dirty gloves. Place the mass change samples horizontally in the cooling rack.

Step 5

After the mass change samples have been removed, remove the remaining containers one at a time.

Step 6

Immediately pour the material from any bottles that are not to be used for the mass change determination into one container as each is removed from the RTFO. Scrape the bottles to remove at least 90% of the remaining residue from each of the bottles. While the residue from each bottle is being scraped, the remaining bottles shall remain in the oven with the fan, heat, and air on. The final bottle must be removed from the oven within 5 minutes of the removal of the initial container.

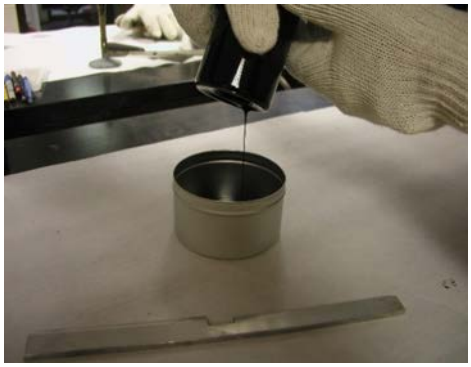


Figure 24: Pouring residue into a single container

Figure 25: Scraping material from the wall of the container

Step 7

When all of the material has been collected into the container, stir the contents to homogenize the sample, avoiding addition of air bubbles. A glass or metal rod is preferable for this purpose.

Step 8

Allow the mass change containers to cool for 60 to 180 minutes. After cooling, determine the mass using the same balance that was used to determine the initial mass.

Mass Change Bottles: Be careful to notice the appearance of any asphalt that has flowed out of the container. If it is apparent that asphalt has flowed out of the container, discard that sample.

Calculations

Determine the change in mass of the bottles whose mass was determined on the 0.001 g balance. The mass change shall be reported as the average of two sample containers.

M_e = mass of empty container

M_i = initial mass of sample and container

M_f = final mass of sample and container

$$\%\ change = \frac{(M_i - M_e) - (M_f - M_e)}{(M_i - M_e)} \times 100$$

Example Calculations

Mass Change Bottle #1:

Empty mass of Empty Container #1 ($M_{e,1}$) = 177.1893 g

Initial Mass of Sample and Container #1 ($M_{i,1}$) = 212.2893 g

Final Mass of Sample and Container #1 ($M_{f,1}$) = 212.1617 g

$$\%\ change = \frac{(212.2893 - 177.1893) - (212.1617 - 177.1893)}{(212.2893 - 177.1893)} \times 100 = 0.364\%$$

Mass Change Bottle #2:

Empty mass of Empty Container #2 ($M_{e,2}$) = 171.9478 g

Initial Mass of Sample and Container #2 ($M_{i,2}$) = 206.7478g

Final Mass of Sample and Container #2 ($M_{f,2}$) = 206.6331 g

$$\%\ change = \frac{(206.7478 - 171.9478) - (206.6331 - 171.9478)}{(206.7478 - 171.9478)} \times 100 = 0.330\%$$

Average Percent Mass Change:

$$\frac{0.364\% + 0.330\%}{2} = \mathbf{0.347\%}$$

Interpreting and Utilizing the Test Results

The results of AASHTO T 315 are commonly used in conjunction with AASHTO M 320 and AASHTO R 29 to determine or verify the performance grade of the asphalt binder. In accordance with AASHTO M 320, the mass change in the asphalt binder must be less than 1.00%. The residue from the RTFO is tested in the DSR (AASHTO T 315) and undergoes long-term conditioning in accordance with AASHTO R 28.

Common Errors

- The fan is not turned on during the preheating of the oven.
- The sample bottles are not rotated after pouring.
- The air outlet orifice is not positioned properly.
- After combining the asphalt into a collection container, the asphalt is not thoroughly stirred to recombine.
- The equipment is not calibrated and standardized at the correct interval or performed incorrectly.

Data Sheets

Raw Data			
Bottle #1		**Bottle #1**	
Empty mass of Empty Container #1 ($M_{e,1}$)		Empty mass of Empty Container #2 ($M_{e,2}$)	
Initial Mass of Sample and Container #1 ($M_{i,1}$) =		Initial Mass of Sample and Container #2 ($M_{i,2}$) =	
Final Mass of Sample and Container #1 ($M_{f,1}$)		Final Mass of Sample and Container #2 ($M_{f,2}$)	

Calculations			
Bottle #1		**Bottle #1**	
$$\%\ change = \frac{(M_i - M_e) - (M_f - M_e)}{(M_i - M_e)} \times 100$$			
Percent Mass Change from Sample Container #1:		Percent Mass Change from Sample Container #2:	
Average Percent Mass Change:			

AASHTO T 350, Standard Method of Test for Multiple Strain Creep Recovery (MSCR) Test of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

Background Information

The MSCR test was developed as a call to the need for a standardized test procedure for determining the elastic response and the presence of polymer modifiers in asphalt binder. It is intended to replace PG+ tests, such as elastic recovery (AASHTO T 301). Tests such as AASHTO T 301 may indicate the presence of modifiers, but do not measure the performance of binder. In addition, the elastic recovery test is time-consuming (it can take 4 or 5 hours to complete), while the MSCR test takes only a few minutes to run and uses the same apparatus that is already utilized in many laboratories to perform AASHTO T 315. A dynamic shear rheometer (DSR) is used to determine the percent of recovery and nonrecoverable creep compliance of asphalt binders. Nonrecoverable creep compliance (Jnr), as described in AASHTO T 350, is the residual strain in a specimen after a creep and recovery cycle divided by the stress applied, kPa-1. The test is performed on materials that have been conditioned in the rolling thin-film oven (AASHTO T 240). The elastic response of the asphalt binder is determined at two stress levels at a specified temperature, as determined from AASHTO M 332. The sample is subjected to 10 cycles at each of the two stress levels. For each cycle, stress is first applied to the sample, and then the load is removed and allowed to recover while the response of the material is measured.

Significance and Use

This test is used in conjunction with specification AASHTO M 332, to determine the performance grade (PG) of an asphalt binder. The method is designed to identify the presence of elastic response in an asphalt binder. Nonrecoverable creep compliance has been shown to be an indicator of the resistance of an asphalt binder to permanent deformation under repeated load (rutting). This test is typically run at the same time as AASHTO T 315 and can be performed on the same RTFO-conditioned sample.

Related Tests, Practices and Specifications

- AASHTO M 322, Standard Specification for Performance-Graded Asphalt Binder Using Multiple Stress Creep Recovery (MSCR)
- AASHTO T 240, Standard Method of Test for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)
- AASHTO T 301, Standard Test Method for Elastic Recovery Test of Asphalt Materials by Means of a Ductilometer

- AASHTO T 315, Standard Method of Test for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

Timeline for Completion

Prep Time: 2 hours

The sample must first be conditioned in the rolling thin-film oven in accordance with AASHTO T 240, which takes approximately 2 hours.

Time to Perform Procedure: 35 minutes

Approximately 10 minutes to prepare the sample, 20 minutes to mount, trim, condition, and test the sample, and 5 minutes of clean-up.

If the test is run on a sample that has already been tested in accordance with AASHTO T 315 (common), then the preparation and mounting time is not necessary. A 1-minute relaxation period will be observed, and the then testing itself will take approximately 5 minutes.

TOTAL TIME: 35 minutes

Apparatus

Dynamic Shear Rheometer – Consisting of parallel metal plates, an environmental chamber, a loading device, and a control and data acquisition system as described in Section 6 of AASHTO T 315. The device must operate in stress-controlled mode; 25-mm parallel plates are used for the MSCR test.

Specimen Mold (Optional) – A silicone mold may be used to form test specimens to mount into the DSR test apparatus. Alternatively, the sample may be transferred to the test plates through a direct-pour method, as described in the AASHTO T 315 lab manual.

Cleaning Materials – Cloths, swabs, paper towels, or other materials for cleaning the test plates. A solvent such as mineral oil, citrus based cleaner, mineral cleaner, or toluene is used to clean the asphalt off of the test plates. Acetone is needed to remove the solvent residue from the plates.

Preparation of DSR

Step 1
Prepare the DSR in accordance with the manufacturer's instructions. The process for each make, model, and manufacturer will vary. If this test is to be performed on a sample that has

already been tested in accordance with AASHTO T 315, the DSR has already been prepared, and these steps can be skipped.

Step 2
Ensure that the plates have been thoroughly cleaned and are free from scratches and jagged edges. Install the plates into the rheometer.

Step 3
Select the testing temperature in accordance with AASHTO M 332. Set the DSR temperature control system to the appropriate temperature and allow the temperature to stabilize to within ±0.1°C.

Step 4
Determine the zero gap level of the rheometer:

If the rheometer does not have a normal force transducer (rare) – Manually spin the top plate while bringing the plate down so that it makes contact with the bottom plate. The zero gap level has been reached when the top plate stops spinning.

If the rheometer does have a normal force transducer (common) – Close the gap between the two plates. When the plates come in contact, set the normal force at zero. On most modern DSRs, this process is automated and is performed through the computerized control system accompanying the device.

Step 5
Preheat the plates:

1. Adjust the plates in position to approximately 1 mm.
2. Adjust the temperature control system to the test temperature to be used.

Sample Preparation

Step 1
It is common to use the same sample that is used to perform AASHTO T 315. If this is the case, the sample will already be mounted in the DSR.

Step 2
When performing the MSCR test on a sample that has already been tested in accordance with AASHTO T 315, allow for a 1-minute relaxation period before initiating MSCR testing.

Step 3
Samples should be conditioned in the rolling thin-film oven (RTFO) in accordance with AASHTO T 240.

Step 4
If the sample has not already been mounted in the DSR, follow the procedure in AASHTO T 315 for mounting and trimming the test specimen.

Procedure

Step 1
Bring the specimen to ±0.1°C of the test temperature.

Step 2
Allow the specimen to remain at the test temperature for 10 minutes before starting the test. Most modern rheometers are equipped with software that automates this step in the test procedure.

Step 3
The following steps are performed automatically by the DSR once the test temperature has been maintained for 10 minutes and the procedure has been initiated in the DSR software:

1. The specimen is subjected to a constant stress creep at 0.1 kPa for 1.0 seconds. The material is then allowed to recover (no stress applied) for 9.0 seconds. This process is repeated for 20 cycles. The first 10 cycles are for conditioning the specimen, and the second 10 cycles are used for collecting recovery data.

2. The specimen is then subjected to a constant stress creep at 3.2 kPa for 1.0 seconds. The material is then allowed to recover (no stress applied) for 9.0 seconds. This process is repeated for 10 cycles and the recovery data is collected.

3. Stress and strain are recorded every 0.1 seconds for the creep cycles (when stress is applied) and at least every 0.45 seconds for the recovery cycles. In addition, peak strain at 1.0 seconds into each cycle, and recovered strain 10.0 seconds into each cycle must be recorded.

Why Two Stress Levels? The material is subjected to a 0.1-kPa stress level and a 3.2-kPa stress level in order to evaluate the difference in performance of the asphalt binder in the linear and non-linear region of behavior. The 0.1-kPa stress level is within the linear region of a binder's behavior, and the 3.2-kPa stress level is at the end of the linear region.

Reported Raw Data

Typically the following raw data is collected for each of the last 10 cycles at the 0.1-kPa stress level, and the 10 cycles at the 3.2-kPa stress level. Many rheometers are equipped with software that records the necessary data and performs the calculations automatically.

- Initial strain at the beginning of the creep portion of each cycle, $\in_0$.
- Strain at the end of the creep portion of each cycle (after 1.0 second), $\in_c$.
- Adjusted strain value at the end of the creep portion (after 1.0 second) of each cycle, $\in_1$, calculated as follows:

  $$\in_1 = \in_c - \in_0$$

- The strain value at the end of the recovery portion (after 10.0 seconds) of each cycle, $\in_r$.
- Adjusted strain value at the end of the recovery portion (after 1.0 second) of each cycle, $\in_{10}$, calculated as follows:

  $$\in_{10} = \in_r - \in_0$$

Calculations

For the last 10 cycles at the 0.1-kPa stress level, and the 10 cycles at the 3.2-kPa stress level, calculate the percent recovery as follows. Many rheometers are equipped with software that performs these calculations automatically.

Percent recovery, $\in_r$ (0.1, N) for *N*=1 to 10 is calculated as follows:

$$Percent\ Recovery, \in_r (0.1, N) = \frac{(\in_1 - \in_{10}) \times 100}{\in_1}$$

Percent recovery, $\in_r$ (0.1, N) for *N*=1 to 10 is calculated as follows:

$$Percent\ Recovery, \in_r (3.2, N) = \frac{(\in_1 - \in_{10}) \times 100}{\in_1}$$

Calculate the average percent recovery at 0.1 kPa and 3.2 kPa.

$$R_{0.1} = \frac{SUM[\in_r (0.1, N)]}{10} \; for\ N = \ 11\ to\ 20$$

$$R_{3.2} = \frac{SUM[\in_r (3.2, N)]}{10} \; for\ N = 1\ to\ 10$$

Calculate the nonrecoverable creep compliance for each of the last 10 cycles at 0.1 kPa, $J_{nr}(0.1, N)$, kPa^{-1}, as strain/stress:

$$J_{nr}(0.1, N) = \frac{\epsilon_{10}}{0.1}$$

Calculate the nonrecoverable creep compliance for each of the last 10 cycles at 3.2 kPa, $J_{nr}(3.2, N)$, kPa^{-1}, as strain/stress:

$$J_{nr}(3.2, N) = \frac{\epsilon_{10}}{3.2}$$

Calculate the average nonrecoverable creep compliance at 0.1 kPa, $J_{nr0.1}$, kPa^{-1}:

$$J_{nr_{0.1}} = \frac{SUM[J_{nr}(0.1, N)]}{10} \; for \; N = 11 \; to \; 20$$

Calculate the average nonrecoverable creep compliance at 3.2 kPa, $J_{nr3.2}$, kPa^{-1}:

$$J_{nr_{3.2}} = \frac{SUM[J_{nr}(3.2, N)]}{10} \; for \; N = 1 \; to \; 10$$

Calculate the percent difference in nonrecoverable creep compliance between 0.1 kPa and 3.2 kPa:

$$J_{nr_{diff}} = \frac{[J_{nr_{3.2}} - J_{nr_{0.1}}] \times 100}{J_{nr_{0.1}}}$$

Interpreting and Utilizing the Test Results

The results of AASHTO T 350 are commonly used in conjunction with AASHTO M 322 to determine the performance grade of an asphalt binder.

Common Errors

Most common errors associated with AASHTO T 350 are also typical of AASHTO T 315. In addition, the other commonly-observed errors include:

- Ten conditioning cycles were not performed at 0.1 kPa prior to the 10 cycles used for measurements and calculations.
- Calculations were performed incorrectly.

Data Sheet

MSCR Test on RTFO-Conditioned Binder	
Sample Number	
PG Grade	
Test Temperature	
Average Percent Recovery at 0.1 kPa, $R_{0.1}$	
Average Percent Recovery at 2.2 kPa, $R_{3.2}$	
Nonrecoverable creep compliance at 0.1 kPa, $J_{nr0.1}$, kPa^{-1}	
Nonrecoverable creep compliance at 3.2 kPa, $J_{nr3.2}$, kPa^{-1}	
Percent difference between J_{nr} at 0.1 kPa and 3.2 kPa, J_{nrdiff}	

AASHTO R 28, Standard Method of Test for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)

Background Information

The PAV was adopted for asphalt testing as a result of the Strategic Highway Research Program (SHRP) in 1992. This practice is used to condition asphalt binder by exposing them to elevated temperature and pressure. It is intended to simulate in-service long-term aging of asphalt binders.

Significance and Use

This practice is used to simulate 5 to 10 years of in-service aging of asphalt binder. It is used in conjunction with AASHTO M 320 and AASHTO R 29 to condition samples for further testing in the Dynamic Shear Rheometer (AASHTO T 315), Bending Beam Rheometer (AASHTO T 313), and the Direct Tension Test (AASHTO T 314). PAV conditioning is an important step in determining the performance grade (PG) of an asphalt binder. Samples are typically conditioned in the rolling thin-film oven test prior to PAV conditioning. This procedure produces no test results. It is utilized to condition the asphalt material so that it can be utilized for other test procedures.

Related Tests, Practices and Specifications

- AASHTO M 320, Standard Specification for Performance-Graded Asphalt Binder
- AASHTO R 29, Grading or Verifying the Performance Grade (PG) of an Asphalt Binder
- AASHTO T 240, Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)
- AASHTO T 313, Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)
- AASHTO T 314, Determining the Fracture Properties of Asphalt Binder in Direct Tension (DT)
- AASHTO T 315, Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

Timeline for Completion

Prep Time: Approximately 2 hours

Material is typically conditioned in the rolling thin-film oven before performing this procedure.

Time to Perform Procedure: 21 hours

Condition binder in pressurized aging vessel. Optional degassing of conditioned material follows. If the sample is to be tested in accordance with AASHTO T 314, degassing must be performed.

TOTAL TIME: 21 hours

Apparatus

Pressurized Aging Vessel (PAV) – A system capable of holding at least 10 sample pans and maintaining specified temperatures and pressures as described in Section 6 of AASHTO R 28. The apparatus must be equipped with a means of recording temperature throughout the conditioning process to the nearest 0.1°C. Most modern systems include a heating system and pressurizing system that are integral to the unit. Figure 26 depicts a typical pressurized aging vessel. The calibration of the temperature detector and pressure gauge on the device must be standardized every six months in accordance with Section 9 of AASHTO R 28.

Figure 26: Pressurized aging vessel

Stainless Steel Pans – Stainless steel pans for holding the asphalt binder during the conditioning process (Figure 27).

Figure 27: Stainless steel pans

Balance – A balance for determining the mass of the specimens.

Vacuum Degassing Oven – As described in Section 6 of AASHTO R 28. If the material conditioned in accordance with this procedure is to be used for performing AASHTO T 313 and T 315, the use of a degassing oven is optional. If the material is to be used for performing AASHTO T 314, the degassing procedure must be performed.

Commercial Bottled Air – A regulated source of breathing quality bottled air for pressurizing the pressurized aging vessel during the conditioning period.

Figure 28: Bottled air

Sample Preparation

Typically, the asphalt binder is conditioned in accordance with AASHTO T 240 (RTFO) prior to performing this procedure. The binder may be poured directly from the RTFO collection container into each of several PAV pans to be tested at a later time. Alternatively, the binder may be reheated to conditioning temperature in the collection container, stirred, and poured

into each of several pans. If the sample has already been poured into pans and allowed to cool, reheat the pans to conditioning temperature.

Preparation of the Apparatus

Preheat the pressure vessel and the pan holder to the test temperature as determined by AASHTO M 320.

Figure 29: Placing sample holder in the chamber

Procedure

Step 1

Place a stainless steel pan on a tared balance, and pour 50 ± 0.5 g of asphalt binder into the pan. Repeat this process with any other pans that will be used.

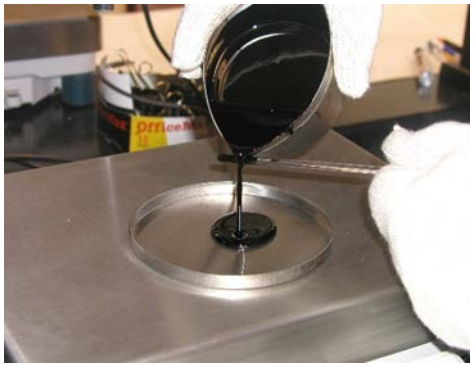


Figure 30: Pouring asphalt binder into pans

Step 2

After the desired number of pans have been poured, remove the sample holder from the vessel. Place each pan in the sample holder, and then replace the sample holder into the vessel. This process should be done quickly, so as to avoid cooling of the vessel and pan holder.

Figure 31: Placing sample pans in the holder

Step 3

Carefully secure the lid, making sure any gaskets are in place, and tightening the bolts according to the manufacturer's recommendations.

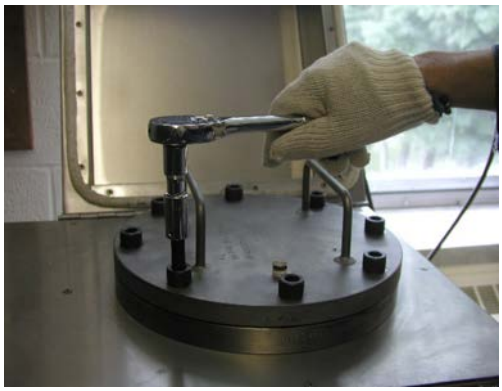


Figure 32: Securing the lid to the conditioning chamber

Step 4

Start the conditioning process. On most modern devices, the conditioning process is automated once initiated through the device's control system. Once the temperature inside the pressure vessel is within 20°C of the conditioning temperature, an air pressure of 2.1 ± 0.1 MPa is applied to the system. Maintain the temperature and pressure within the vessel for 20 h ± 10 minutes.

Step 5

At the end of the conditioning period, the pressure is reduced to atmospheric pressure. The reduction of pressure must occur slowly over a 9 ± 1 minute period.

Releasing the Pressure: It is important to equalize the internal and external pressures on the PAV slowly to avoid bubbling or foaming of the asphalt binder.

Step 6

Evaluate the data from the temperature and pressure recorders. If the temperature falls out of the specified range by ±0.5˚C for more than 60 minutes during the aging period, declare the procedure invalid.

Step 7

After depressurization, remove the pan holder from the PAV and place the pans in an oven at approximately 163˚C. Make a note if the temperature exceeds 175˚C.

Step 8

Scrape the contents of each pan into a single container. Stir to combine.

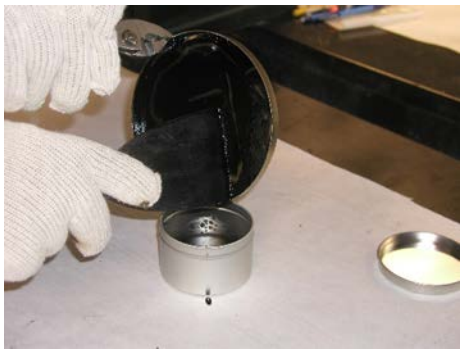


Figure 33: Pour material into a single container

Step 9

If the degassing procedure is to be done, perform the following.

Preheat the vacuum degassing oven to 170 ± 5˚C.

Figure 34: Degassing oven

Place the container containing the material into the degassing oven and close the lid. Make sure that the O-ring has been installed correctly or the vacuum will not be achieved. Allow the specimen to equilibrate in the vacuum oven for 15 ± 1 minute without the vacuum on.

Figure 35: Placing the sample in the degassing oven

After the sample has equilibrated, quickly turn the vacuum on and set to a pressure of 15 ± 2.5 kPa for 30 ± 1 minute.

At the end of the specified time, release the vacuum and remove the container, torching or stirring with a hot knife to remove any bubbles.

Next Steps

After the PAV conditioning procedure is complete, this material can be used to perform the bending beam rheometer test (AASHTO T 313), the direct tension test (AASHTO T 314), and the dynamic shear rheometer test (AASHTO T 315) to determine the performance grade (PG) of the asphalt binder in accordance with the requirements of AASHTO M 320 and R 29.

Common Errors

- Verification of the calibration of the temperature and pressure sensors are not performed at the correct intervals.
- The PAV sample pans are warped.
- Temperature and pressure are not maintained during the conditioning period for the proper period of time or at the correct levels.
- The sample is not stirred after combining the material from each pan.

AASHTO T 313, Standard Method of Test for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)

Background Information

The BBR was adopted for asphalt testing as a result of the Strategic Highway Research Program (SHRP) in 1992. This test is used to determine the flexural creep stiffness of asphalt binders. The test is performed within a temperature range of -36 to 0°C. The test samples are molded prism-shaped beams of asphalt binder. The beam is simply supported and subjected to a constant load at the midpoint. The stiffness of the beam is calculated by dividing the maximum stress by the maximum strain.

Significance and Use

The BBR test measures the flexural creep stiffness of an asphalt binder. The temperature at which the test is performed is determined in accordance with AASHTO M 320 and AASHTO R 29. This temperature is related to the conditions experienced by the pavement in a particular geographical area. Flexural creep stiffness is related to low-temperature thermal cracking of a material.

Related Tests, Practices and Specifications

- AASHTO R 28, Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
- AASHTO R 29, Grading or Verifying the Performance Grade (PG) of an Asphalt Binder
- AASHTO T 240, Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)
- AASHTO T 314, Determining the Fracture Properties of Asphalt Binder in Direct Tension (DT)
- AASHTO M 320, Performance-Graded Asphalt Binder

Timeline for Completion

Prep Time: 3 hours

Warm the PAV-aged binder and pour into prepared beam molds. Allow to condition at room temperature, cool, then demold. Place the samples in the testing bath for another hour to condition. Daily verifications can take up to 30 minutes.

Time to Perform Procedure: 5 minutes

Perform a daily check to ensure the test load and the contact load are able to be applied quickly. After the check, the testing is automatically controlled through the associated software.

TOTAL TIME: 3+ hours

Apparatus

Bending Beam Rheometer (BBR) – A testing system that includes a loading frame and loading system, controlled-temperature bath, data acquisition system, and temperature transducer as described in Section 6 of AASHTO T 313 (Figure 36).

Figure 36: Bending Beam Rheometer

Test Molds – Aluminum molds as described in Section 6.3 of AASHTO T 313.

Verification Equipment – Used to perform the daily standardization procedures. Equipment needed includes thermometers, calibrated masses, standard height blocks, a standard thin steel beam, and a standard thick steel beam.

Plastic Sheeting – Clear plastic sheeting for lining the interior faces of the mold sections.

Petroleum-based Grease – A petroleum-based grease used to hold the plastic strips in place.

Glycerol-Talc Mixture – To coat the end pieces of the aluminum molds.

Bath fluid – Typical bath fluids include ethanol, methanol, and glycol-methanol mixtures.

Trimming tool – For trimming the specimens prior to demolding.

Preparation of the BBR Testing System

Using the computerized data acquisition system, adjust the temperature of the BBR bath to the temperature that will be used for testing. If this test is performed in order to determine or

verify the performance grade (PG) of an asphalt binder, select the test temperature in accordance with AASHTO M 320 and AASHTO R 29.

Complete the daily standardization procedures each day before performing the test. The standardization procedures are described in Section 10 of AASHTO T 313 and include the following:

- Verification of Temperature Transducer
- Verification of Freely Operating Air Bearing
- Verification of Displacement Transducer
- Daily Overall System Check
- Verification of Contact Load
- Verification of Test Load

Assembling the Test Molds

Step 1
Assemble two sets of molds, each of which contain 1 aluminum base plate, 2 side plates, 2 end pieces, 3 plastic strips, and 2 rubber O-rings.

Assembling Molds: When selecting side pieces, it is a good idea to measure the thickness and select pieces that are a close match in that dimension. The thickness of the end pieces will have a significant impact on the thickness of the prepared sample.

Step 2
Apply a thin layer of petroleum grease to the interfaces of the aluminum side and bottom pieces.

Figure 37: Applying petroleum grease to molds

Step 3
Place the plastic strip over the faces of the aluminum molds and rub the plastic with firm finger pressure.

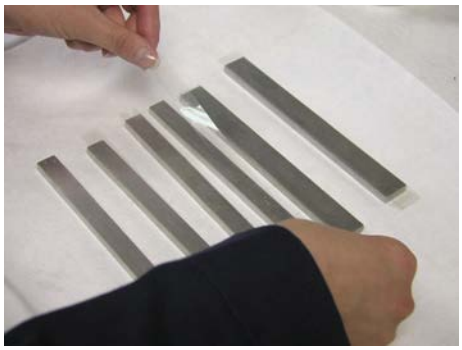


Figure 38: Placing plastic strips over molds

Step 4

Assemble the beam molds as shown in Figure 39.

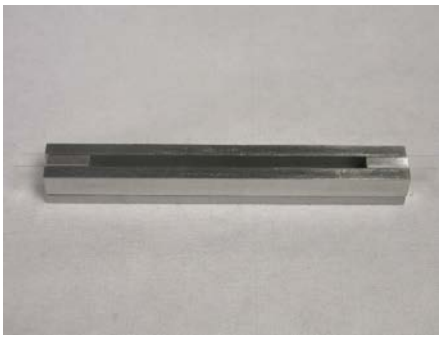


Figure 39: Assembled mold

Step 5

Put one rubber O-ring on each end of the beam mold.

Figure 40: Placing O-ring on the end of the mold

Step 6

Pull the plastic strips from the ends to ensure that there are no air bubbles or gap between the plastic strips and beam side plates.

Step 7
Lightly coat the inside faces of the end pieces with the glycerol and talc mixture.

Sample Preparation

Step 1
Heat the sample at a minimum temperature until the sample is sufficiently fluid to pour. The sample should be covered and stirred occasionally. For performance grading in accordance with AASHTO M 320 and R 29, the material should be conditioned as per AASHTO T 240 (RTFO) and R 28 (PAV) prior to running this test. If the material is also to be tested in accordance with T 314 (DT), it must be degassed in accordance with R 28 (PAV).

Step 2
Holding the sample container 20 to 100 mm from the top of the mold, pour a continuous stream of asphalt from one end of the opening to the other, overpouring slightly. Plan to complete testing within four hours of this time.

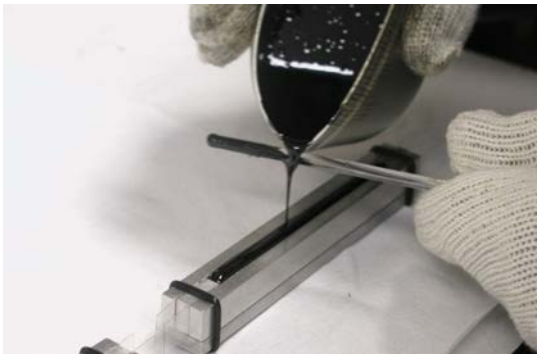


Figure 41: Pouring asphalt binder into the mold

Step 3
Allow the sample to cool for 45 to 60 minutes at room temperature.

Step 4
After the sample has cooled, gently heat a trimming tool and trim the excess asphalt off so that the material in the mold is flush with the top of the mold.

Figure 42: Trimming test specimens

Step 5

To demold the specimens, cool the mold and material in an ice bath or freezer at -5˚C ± 7˚C for 5 to 10 minutes. Do not place the specimen in the testing bath at this time, as this may cause the temperature of the bath to fluctuate more than ±0.2˚C.

Step 6

Remove the O-rings from the mold, then carefully slide the bottom piece and side pieces off. Remove the plastic sheeting and carefully place the sample in the test bath of the BBR at the testing temperature.

Demolding Specimens: Distortion of the beam should be avoided. If the plastic sheeting is sticking to the sample, you may remove the last layer of sheeting as the specimen is being placed into the sample bath. To avoid specimen distortion, hold the sample mold and specimen vertically.

Step 7

Condition the samples in the test bath for 60 ± 5 minutes prior to testing.

Procedure

Step 1

Prior to testing, check the contact load and test load. This check is vital, as this check will ensure that the switch from the contact load to the test load is accomplished in the allowable time frames. Failure for the switch to be accomplished during testing will result in the invalidation of the test, and for a new sample to be prepared.

Step 2

Place the thick steel beam into the sample supports. Use the test load regulator to gently increase the force on the beam to 980 ± 50 mN. Switch from the test load to the contact load

and adjust the force on the beam to 35 ± 10 mN. Switch between the test load and the contact load at least 4 times.

Step 3
After the contact and test load have been verified, enter the sample information into the system. Do not load the specimen into the loading supports until the test is ready to be performed, as it shall not be in contact with the loading head in excess of 10 seconds. Load the sample onto the supports and manually apply a 35 ± 10 mN load.

Step 4
Activate the automatic test system. At this point, the testing system will apply a seating load of 980 mN for 1 second, and then reduce the load back to 35 ± 10 mN for a 20-second recovery period. Then, the system will apply the test load of 980 ± 10 mN for 240 seconds. Force and deflection data are captured automatically by the testing system.

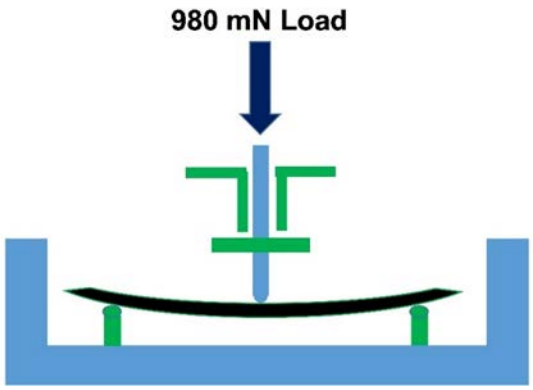


Figure 43: Test load is applied to specimen

Example Report

The BBR software typically generates a report with the information shown in Table 4 and Table 5.

Table 4: Test Information

Project Information	Project Data
Project	**AJB123**
Operator	**MPK**
Specimen	**AJB123 – PAV**
Time	**11:27:03**
Date	**1/12/2015**
File	**0818154.DAT**
Target Temp	**23.0°C**
Actual Temp	**14.3°C**
Soak Time	**0.0 s**
Beam Width	**12.70 mm**
Thickness	**6.35 mm**
Conf. Test	**2.199e + 008**
Date	**1/13/2015**
Load Const	**0.24**
Defl ConstL	**0.0024**
Date	**1/13/2015**

Table 5: Test Results

T Time (s)	P Force (N)	d Defl (mm)	Measured Stiffness (kPa)	Estimated Stiffness (kPa)	Difference %	m-value
8	0.9859	0.9126	87030.0	87060.0	0.03532	0.176
15	0.9894	1.022	77990.0	77930.0	-0.08120	0.175
30	0.9913	1.158	68690.0	68990.0	0.04809	0.175
60	0.9910	1.308	61110.0	61110.0	0.004487	0.174
120	0.9908	1.475	54150.0	54150.0	-0.001551	0.174
240	0.9906	1.664	48010.0	48000.0	-0.005077	0.174

Regression Coefficients:

- a = 5.100
- b = -0.1784
- c = 0.001020
- R^2 = -0.999996

Interpreting and Utilizing the Test Results

The results of AASHTO T 315 are commonly used in conjunction with AASHTO M 320 and AASHTO R 29 to determine or verify the performance grade of the asphalt binder. If the creep stiffness of the sample is above 300 MPa but below 600 MPa, additional testing may be done with the Direct Tension Test (AASHTO T 314) in order to determine the performance grade (PG) of the material.

Common Errors

- Daily standardization procedures are not performed.
- The beams are often made by pouring the liquid asphalt back and forth in the container rather than in one continuous stream.
- Improper release agents are used on the molds.

Data Sheet

BBR Data for Verifying Performance Grade	
Sample Name:	
Test Temperature:	
Creep Stiffness (s), MPa:	
m-value:	

AASHTO T 314, Standard Method of Test for Determining the Fracture Properties of Asphalt Binder in Direct Tension (DT)

Background Information

The DT Test was adopted for asphalt testing as a result of the Strategic Highway Research Program (SHRP) in 1992. The direct tension tester is used to simulate thermal cooling and to predict the temperature at which thermal cracking will occur on a roadway. The direction tension test determines the failure strain of asphalt binders at low temperatures.

Significance and Use

This test is typically performed on materials that have been conditioned in the rolling thin-film oven (RTFO) in accordance with AASHTO T 240 and the pressurized aging vessel (PAV) in accordance with AASHTO R 28. The results of testing are used in conjunction with specification AASHTO M 320 and AASHTO R 29 to grade or verify the performance grade of an asphalt binder. It is also used in conjunction with AASHTO R 49 for determination of the low-temperature performance grade of asphalt binders. In accordance with AASHTO M 320, as asphalt binder may be used to test asphalt binders that have a high creep stiffness, between 300 and 600 MPa, as determined by the bending beam rheometer test, AASHTO T 313. Asphalt binders with a creep stiffness below 300 MPa meet the grading requirements in question, and DT testing is not needed.

Related Tests, Practices and Specifications

- AASHTO M 320, Standard Specification for Performance-Graded Asphalt Binder
- AASHTO R 29, Standard Practice for Grading or Verifying the Performance Grade of an Asphalt Binder
- AASHTO R 49, Standard Practice for Determination of Low-Temperature Performance Grade (PG) of Asphalt Binders
- AASHTO T 240, Standard Method of Test for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)
- AASHTO T 313, Standard Method of Test for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)

Timeline for Completion

Prep Time: 24 hours

Samples are first conditioned in accordance with AASHTO T 240 and R 28. Approximately 2 ½ hours of prep time are needed to assemble molds, pour, and condition samples prior to running the direct tension test.

Time to Perform Procedure: 30 minutes

Each prepared sample is tested under tension in the testing apparatus.

TOTAL TIME: 30 MINTUES

Apparatus

Direct Tension Tester – A testing system as specified in Section 6 of AASHTO T 314 that consists of a tensile loading machine, a specimen gripping system, and a temperature control chamber (either fluid, common, or air bath, which is rare), and a data acquisition system. The tester is used to measure the stress and strain at failure as the specimen is subjected to a constant rate of elongation

Temperature Control: Fluid-based baths are far more common than air-based baths. An aqueous mixture of 42% potassium acetate and 58% deionized water by weight is typically used. Alcohol can have a significant effect on the fracture properties of asphalt binder, lowering the failure properties of the material under test, and therefore shall not be used.

Specimen Molds – A minimum of six specimen molds are needed to perform the test. Each mold consists of two aluminum side plates (Figure 44), an aluminum base plate, two acrylic end tabs, and Teflon-coated release paper (Figure 45).

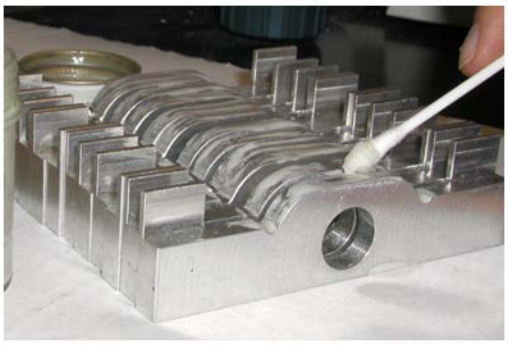


Figure 44: Aluminum side plates

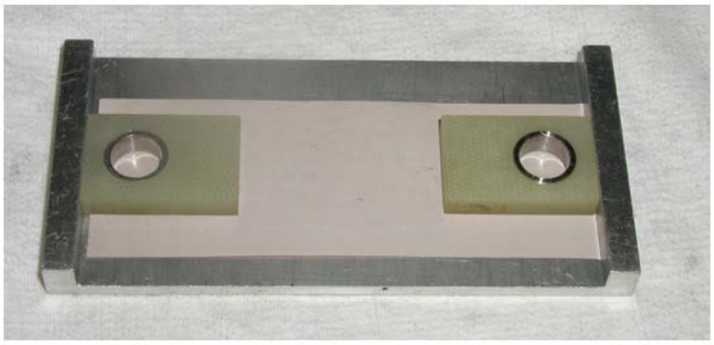


Figure 45: Aluminum base plate with end tabs and release paper

Release Agent – A 50/50 mixture of glycerin and talc (by mass).

Liquid-in-Glass Thermometer – Used to standardize the temperature detector that is integral to the testing system.

Forced-air Convection Oven – Maintained at 160 ± 5°C for heating the asphalt binder.

Cleaning Agents – Varsol, mineral spirits, etc. for cleaning the molds.

Cotton Cleaning Cloths – for wiping and cleaning molds.

Calibration and Standardization

Verification of the calibration of the displacement transducer and elongation rate should be performed every six months in accordance with Section 9 of AASHTO T 314. In addition, the temperature detector that is integral to the testing system must be standardized at least annually.

Sample Preparation

Samples are typically conditioned in the rolling thin-film oven (RTFO) in accordance with AASHTO T 240 and the pressurized aging vessel (PAV) in accordance with AASHTO R 28 prior to running this test. Heat the asphalt binder sample until it is sufficiently fluid to pour prior to transferring the material to the molds.

Mold Assembly

Assemble six tests molds as follows.

Apply the glycerin and talc mixture to the middle surfaces of each of the 12 side plates so that a thin, uniform layer covers the entire surface.

Place a release paper and 2 end tabs on each base plate, as shown in Figure 46.

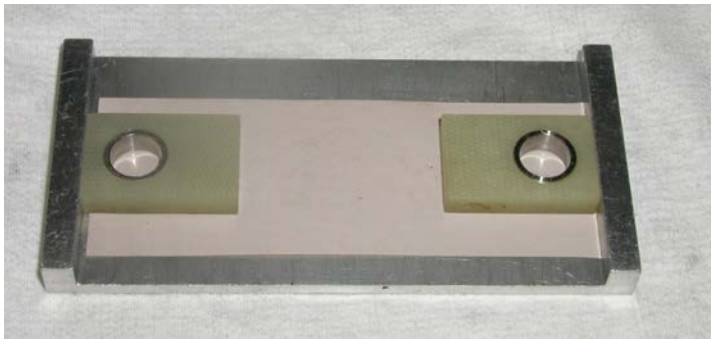


Figure 46: Base plate with release paper and end tabs.

Insert two side plates on top of the base plate, release paper, and end tabs as show in Figure 47.

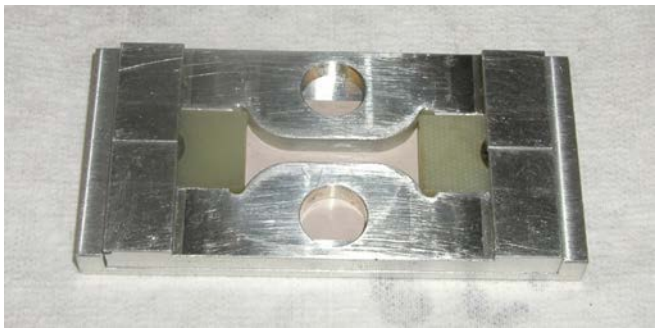


Figure 47: Side plates inserted into mold

Pouring and Molding Test Specimens

Step 1
Set the cooling bath test temperature, as determined by AASHTO M 320 and R 29.

Step 2
Heat the asphalt until it is sufficiently fluid to pour. Stir the sample prior to pouring.

Step 3
Place the assembled molds into the same oven that is used to heat the asphalt binder for no more than 3 minutes.

Figure 48: Placing molds in oven

Heating the Molds: Care should be taken to allow the molds to heat in the oven for no longer than 3 minutes. Heating times longer than 3 minutes may affect the release properties of the glycerin and talc mixture.

Step 4

Remove the molds from the oven and immediately begin pouring the hot asphalt binder into the mold. Start from one end of the mold cavity and move across the mold in a single pass. The mold should be slightly overfilled, as shown in Figure 49.

Figure 49: Pouring asphalt binder into heated molds

Pouring Technique: It is challenging to pour six molds at a time before the molds cool to the point that pouring becomes difficult. It is acceptable to pour one or two molds at a time. If this is done, the heating of the molds should be staggered so that any one mold is not left in the oven longer than 3 minutes.

Step 5

Allow the specimens to cool at ambient temperature for 30 to 60 minutes.

Step 6

After the cooling period, trim off the excess binder by heating the trimming knife to approximately 165°C and place it so it is flush with the top of the mold. Gently trim the top of the sample my moving the knife from one end of the mold to the other in one pass.

Figure 50: Trimming the test specimens

Importance of Trimming: Use care during the trimming operation so that the asphalt binder is not pulled away from the mold and the bond between the end tabs and asphalt binder is not damaged. Excessive force or an unheated trimming knife may cause deformation of the specimen. Damaged specimens may exhibit a low failure strength.

Step 7

Allow the specimen to sit at ambient temperature for 10 to 15 minutes after trimming.

Demolding the Specimens

Step 1

Place two side plates of an unused aluminum mold into the cooling bath and allow them to cool to the test temperature. These plates will be used to transfer specimens into the test bath.

Step 2

Place an unused aluminum bottom plate upside down on the work area. This plate will be used as the transfer plate. Cover the plate with two release papers so that they completely cover the bottom of the transfer plate.

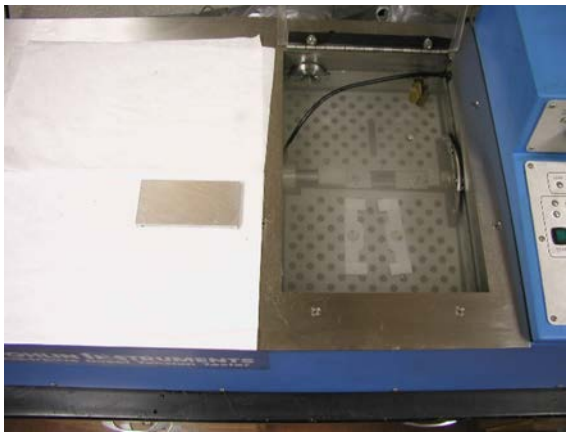


Figure 51: Transfer plate (left) and side plates cooling in bath (right)

Step 3

Gently slide the specimen and the two side plates to one edge of the bottom plate. Pivot and fold down one of the side plates and then replace it. Repeat on the other side of the specimen.

Figure 52: Demolding specimens

Step 4

Repeat the demolding procedure described in Step 3, except this time replace the original side plates with the side plates from the cooling bath.

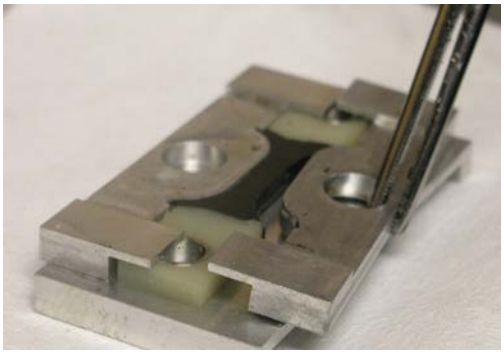


Figure 53: Replacing side plates with cooled side plates

Step 5

Gently remove the bottom plate by turning the mold assembly upside down. Place the assembly on top of the transfer plate, perpendicular to the orientation of the transfer plate. Gently remove the bottom plate from the specimen by sliding it off. Remove the exposed release paper while holding the side plates in place.

Figure 54: Removing release paper

Step 6

Place the upside-down specimen, with the two cold side plates, in the cooling bath. Allow the assembly to cool for a minimum of 2 minutes.

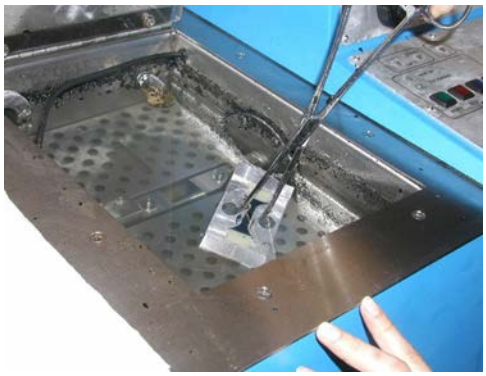


Figure 55: Placing specimen in cooling bath

Step 7

After the 2-minute cooling period, remove the side plates.

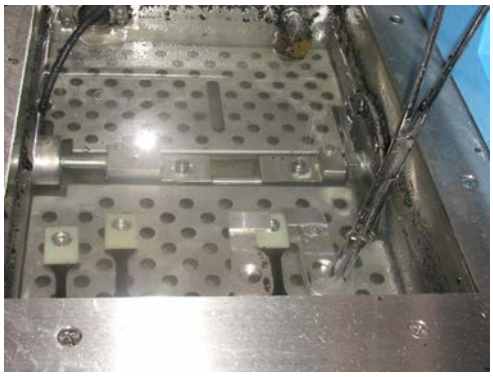


Figure 56: Removing side plates from specimens

Step 8

Flip the specimen so that trimmed side of the specimen is facing up. Specimens should always be tested with the trimmed side facing up.

Test Procedure

Step 1

Allow the specimens to condition at the test temperature for 60 ± 10 minutes.

Step 2

Mount the specimen into the loading frame by matching the holes in the end tabs with the pins on the load frame. It may be necessary to adjust the distance between the pins using the thumb wheel located on the device controls.

Figure 57: Direct tension tester control system

Step 3

Once the specimen is placed on the loading frame, the slack between the specimen and the loading pins is removed, and the test is begun. Most direct tension testers perform these steps automatically once the tests is initiated in the software.

Step 4

The test is performed at a strain rate of 3% per minute, and is continued until failure occurs (i.e. the specimen breaks).

Step 5

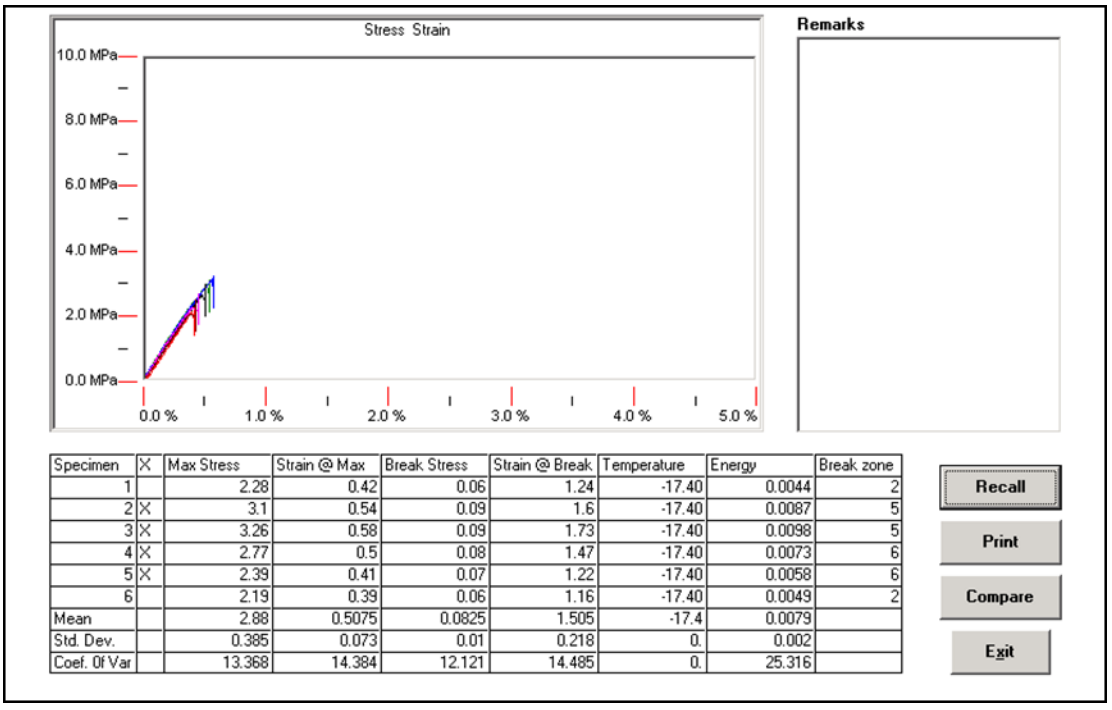
Test all six specimens in the manner described in Steps 1–4 above.

Calculations and Reporting

The software will automatically calculate the failure stress, strain, and energy. Discard the two results with the lowest failure stresses and determine the mean and standard deviation of the four remaining failure values.

Discarding the Two Lowest Failures: It is assumed that inconsistencies related to preparation and mounting of the specimens will result in a reduction of the strength of the specimen, not an increase in strength. Therefore, we discard the two lowest test results when performing the calculations. This is called a Weibull distribution.

If a specimen fails at the throat section instead of at the mid-point, the data for the failure should be recorded, but it should also be noted in the report that the specimen failed at the throat. Figure 58 provides an example of how the results are typically reported by the direct tension software.



Specimen	X	Max Stress	Strain @ Max	Break Stress	Strain @ Break	Temperature	Energy	Break zone
1		2.28	0.42	0.06	1.24	-17.40	0.0044	2
2	X	3.1	0.54	0.09	1.6	-17.40	0.0087	5
3	X	3.26	0.58	0.09	1.73	-17.40	0.0098	5
4	X	2.77	0.5	0.08	1.47	-17.40	0.0073	6
5	X	2.39	0.41	0.07	1.22	-17.40	0.0058	6
6		2.19	0.39	0.06	1.16	-17.40	0.0049	2
Mean		2.88	0.5075	0.0825	1.505	-17.4	0.0079	
Std. Dev.		0.385	0.073	0.01	0.218	0.	0.002	
Coef. Of Var		13.368	14.384	12.121	14.485	0.	25.316	

Figure 58: Typical test results reported by software

Interpreting and Utilizing the Test Results

The results of AASHTO T 314 are commonly used in conjunction with AASHTO M 320, AASHTO R 29, and AASHTO T 313 to determine or verify the performance grade of the asphalt binder.

Common Errors

- Reference equipment used to verify the calibration of the temperature measurement system, load cell, and displacement transducer do not meet the requirements of the standard.
- Verification of the calibration of the temperature measurement system, load cell, and displacement transducer are not performed at the proper interval.
- The demolding procedure is not performed properly.
- The specimen is tested with the trimmed side down instead of up.
- Throat breaks are not noted in the test report.
- The specimens with the two lowest failure values are not discarded.
- The release agent used was not a 50/50 mixture of glycerin and talc.

Data Sheet

Direct Tension Test Data				
Sample Name:				
Date and Time of Test				
Test temperature, nearest 0.1°C				
Rate of Elongation, nearest 0.01 mm/min				
Test Results				
Specimen Number				
Failure Strain, nearest 0.01 percent for each specimen				
Average Failure Strain, 0.01 percent				
Failure Stress, nearest 0.01 MPa for each specimen				
Average Failure Stress, nearest 0.01 MPa				
Peak Load, nearest N for each specimen				
Average Peak Load, nearest N				
Type of Fracture Observed for Each Specimen				

AASHTO R 29, Grading or Verifying the Performance Grade (PG) of an Asphalt Binder

Background Information

This practice describes the testing required to determine the performance grade (PG) of an asphalt binder in accordance with AASHTO M 320. This practice can be used to determine the PG of an unknown asphalt binder, or to verify the PG of a known material.

Related Tests, Practices and Specifications

- AASHTO M 320, Performance-Graded Asphalt Binder
- AASHTO R 28, Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
- AASHTO T 48, Flash and Fire Points by Cleveland Open Cup
- AASHTO T 240, Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)
- AASHTO T 313, Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)
- AASHTO T 314, Determining the Fracture Properties of Asphalt Binder in Direct Tension (DT)
- AASHTO T 315, Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)
- AASHTO T 316, Viscosity Determination of Asphalt Binder Using Rotational Viscometer

Apparatus

Equipment must be available to perform the following tests:

- PAV (AASHTO R 28)
- Flash Point (AASHTO T 48)
- Rolling Thin-Film Oven (AASHTO T 240)
- Bending Beam Rheometer (AASHTO T 313)
- Direct Tension Test – Optional (AASHTO T 314)
- Dynamic Shear Rheometer (AASHTO T 315)
- Rotational Viscosity (AASHTO T 316)

Sample Preparation

For Grading an Unknown Asphalt Binder – A minimum of 400 grams of unconditioned asphalt binder is needed.

For Verifying the Grade of an Asphalt Binder – A minimum of 250 grams of unconditioned asphalt binder is needed.

Procedure – Grading an Unknown Asphalt Binder

To grade an unknown binder, begin DSR testing at 58˚C. Determine the results of G*/sin δ. If the sample fails at 58˚C, increase or decrease the temperature by increments of 6˚C until the value of G*/sin δ ≥ 1.00 kPa. The highest temperature where G*/sin δ ≥ 1.00 kPa will determine the starting value for the PG grade.

Step 1

Perform the DSR on original asphalt binder in accordance with AASHTO T 315. Test the sample initially at 58°C. Increase the test temperature and repeat the test until G*/sin δ ≤ 1.00 kPa.

Step 2

The starting high-temperature grade of the material is the highest temperature where G*/sin δ ≥ 1.00 kPa.

Example – DSR on Original Binder: An unconditioned binder is tested at 58°C with the following results:

G*/sin δ @ 58°C = 1.13 kPa

The binder is retested at higher temperatures with the following results:

G*/sin δ @ 64°C = 1.04 kPa

G*/sin δ @ 70°C = 0.98 kPa

The highest temperature where G*/sin δ ≥ 1.00 kPa is 64°C. Therefore, the starting high-temperature grade of the material is 64°C.

Step 3

Determine the flash point of the original binder according to the requirements set forth in AASHTO T 48. The flash point must exceed 230˚C.

Step 4

Determine the viscosity of the original binder in accordance with AASHTO T 316 at 135˚C. The viscosity must not exceed 3 Pa·s.

Step 5

Perform the RTFO test and determine the mass change in accordance with AASHTO T 240. The sample must not have a mass change ≥ 1.00%.

Step 6

Perform the DSR on the RTFO-conditioned material in accordance with AASHTO T 315. Test the sample initially at the starting grade determined in Step 2. If G*/sin δ ≥2.20 kPa, the temperature from Step 2 is the high-temperature grade of asphalt binder. If G*/sin δ ≤ 2.20 kPa, retest the material at a temperature 6°C lower.

Step 7

The high temperature grade of the asphalt binder is the lowest temperature where G*/sin δ ≥ 2.20 kPa.

Example – DSR on RTFO-Conditioned Binder: An RTFO-conditioned binder is initially tested at 64°C with the following results:

G*/sin δ @ 64°C = 2.13 kPa

The binder is retested a lower temperature with the following results:

G*/sin δ @ 58°C = 2.21 kPa

The highest temperature where G*/sin δ ≥ 2.20 kPa is 58°C. Therefore, the high-temperature grade of the material is 58°C.

Step 8

Condition the RTFO-conditioned material in the PAV in accordance with AASHTO R 28. Determine the temperature at which to perform the PAV conditioning in accordance with Table 6.

Table 6: PAV Conditioning Temperatures

High-Temperature Grade	**PAV Conditioning Temperature**
45–52°C	90°C
58°C or Higher	100°C
Desert Climate	110°C

Step 9

Perform the DSR on the PAV-conditioned material in accordance with AASHTO T 315. Determine the initial DSR test temperature in accordance with Table 7 and the high-temperature grade of the material as determined from Step 7.

Table 7: Selecting DSR Test Temperature for PAV Residue

High-Temperature Grade	**DSR Test Temperature for PAV Residue**
PG 52 – XX	16°C
PG 58 – XX	19°C
PG 64 – XX	22°C
PG 70 – XX	28°C

Step 10

Continue DSR testing on the PAV residue, increasing or decreasing the test temperature at 3°C increments until G*sin δ exceeds 5000 kPa.

Example – DSR on PAV-Conditioned Binder: The high-temperature grade of the material is 58°C, so the DSR test on the PAV-conditioned binder is initially performed at 19°C with the following results:

G*sin δ @ 19°C = 3611 kPa

The binder is retested a lower temperature with the following results:

G*sin δ @ 19°C = 6155 kPa

The lowest temperature where G*sin δ is greater than 5000 kPa is 19°C.

Step 11

Test the PAV-conditioned material in the BBR in accordance with AASHTO T 315. Determine the test temperature in accordance with Table 1 of AASHTO M 320. The temperature for BBR testing corresponds to the test temperature directly below the passing temperature for PAV-conditioned DSR testing.

Step 12

Test two BBR beams according to AASHTO T 313. The value of the slope, m, must be ≥ 0.300 and the value of stiffness, S, must be ≤ 300 MPa. Retest the material, increasing the test temperature at 6° increments until these requirements can be met. New BBR specimens must be made for every change in test temperature. The low-temperature grade determined in

accordance with Table 1 of M 320 based on the first temperature at which the stiffness and m-value criteria for the BBR can be satisfied.

Example – BBR Testing: When performing the DSR on PAV-conditioned binder, the lowest temperature where G*sin δ is greater than 5000 kPa is 19°C. According to Table 1 of AASHTO M 320, the sample is tested in the BBR at -18°C with the following results:

At -18°C, S = 367 MPa and m = 0.294

The binder is retested a higher temperature with the following results:

At -12°C, S = 165 MPa and m = 0.365

The lowest temperature which satisfies the criteria for stiffness and m-value is -12°C. This corresponds to a low-temperature grade of -22°C.

Step 13
If the BBR slope value, m, is ≥ 0.300 and the stiffness, S, is between 300 and 600 MPa, direct tension testing (DTT) in accordance with AASHTO T 314 may be used lieu of the BBR stiffness requirement. The failure strain, Ɛ, must be ≥ 1.00%. Increase the test temperature at 6° increments until this condition is satisfied.

Procedure – Verifying the Grade of an Asphalt Binder

To verify the grade of an asphalt binder, test the binder at the known grade temperatures in accordance with Table 1 of AASHTO M 320. If the material does not meet the criteria in AASHTO M 320 at the known grade temperatures, the material is treated like an unknown grade, and the process for determining the grade of the material must be followed.

Data Sheet

Test/Practice	Results and Sample Information				
Sample Number					
Lot Number					
PG Grade (expected)					
Initials / date(s)					
T 48 - Flash Point Temp (˚C) must exceed 230˚C					
T 316 - Rotational Viscosity ≤ 3 Pa·s @ 135˚C					
T 315 - Original DSR (kPa) ≥ 1 kPa					
T 240 - RTFO % change ≤ 1%					
Discontinue testing if conditions above not met					
T 315 - RTFO DSR ≥ 2.20 kPa					
T 315 - PAV DSR ≤ 5000 kPa					
T 313 - BBR					
Stiffness, S ≤ 300 MPa					
Slope, *m* ≥ 0.300					
T 228 - Specific Gravity (optional)					
Final Grade					

Appendix A: Lab Materials

HMEC Module F Asphalt Binder Tests

Tuesday, March 1, 2016

Please review Page 2 for your grouping and team assignments.

Time	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	Break	Break	Break	Break
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 228 Specific Gravity of Semi-Solid Bituminous Materials
- AASHTO T 316 Viscosity Determination of Asphalt Binder Using Rotational Viscometer
- AASHTO R 28 Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)

Station 2

- AASHTO T 313 Determining the Flexural Creep Stiffness of Asphalt Binder Using a Bending Beam Rheometer (BBR)
- AASHTO T 315 Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)
- AASHTO T 350 Multiple Stress Creep Recovery (MSCR) Test of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

Station 3

- AASHTO T 314 Determining the Fracture Properties of Asphalt Binder in Direct Tension
- AASHTO R 29 Grading or Verifying the Performance Grade of an Asphalt Binder

Station 4

- AASHTO T 240 Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)
- AASHTO T 48 Flash and Fire Points by Cleveland Open Cup

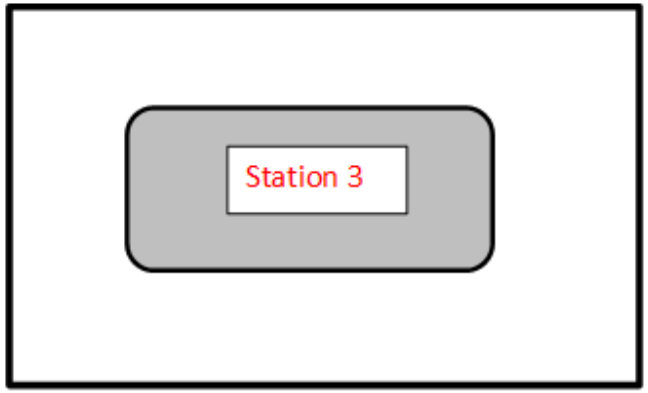
Stations 1, 2, and 4 will be performed in the AMRL Laboratory.

Station 3 will be in the small AMRL Conference Room.

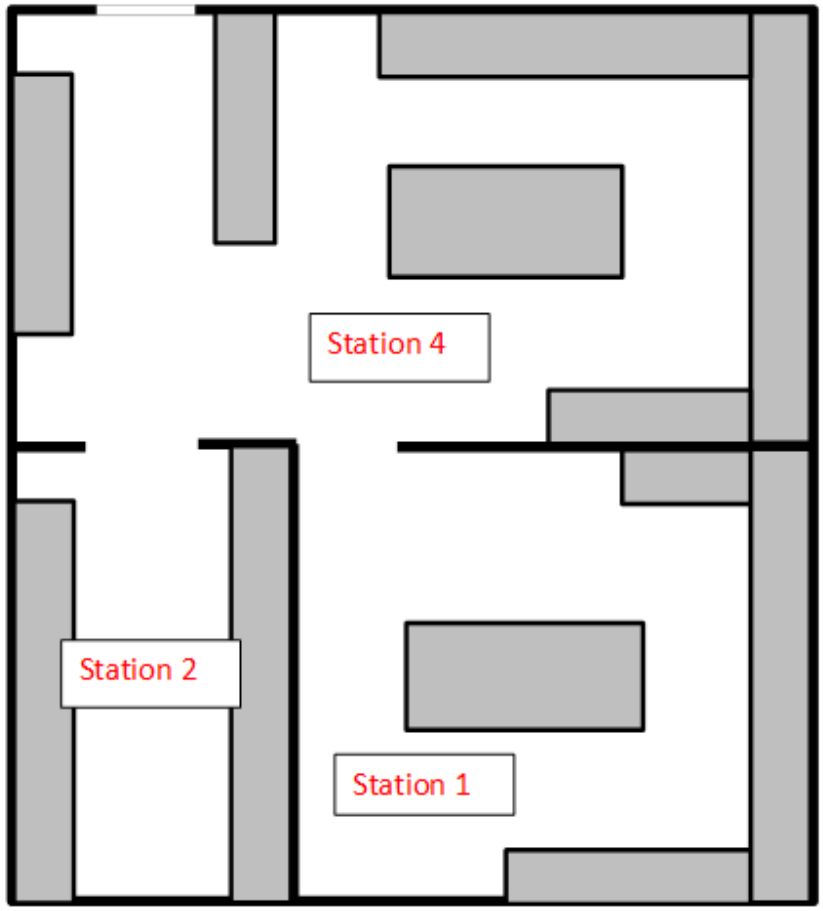
Team Assignments

To Be Determined

AMRL Laboratory Layout for Module F (Asphalt Binder)



Station 3 will be located in the AMRL Conference Room



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 the safety data sheets (SDSs) for more information on each of these substances.

- HiSol Plus (a citrus-based cleaner)
- Acetone
- Glycerin-Talc Mixture
- Ethanol
- 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 laboratory.

Heat

Asphalt binder and ovens will be heated to temperatures of approximately 163°C (325°F). 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.

Station 1: AASHTO T228 Specific Gravity of Semi-Solid Bituminous Materials

$$\text{relative density} = \frac{(\text{C} - \text{A})}{(B - A) - (D - C)}$$

where:

A = mass of pycnometer (plus stopper)

B = mass of pycnometer filled with water (plus stopper)

C = mass of pycnometer partially filled with asphalt binder (plus stopper), and

D = mass of pycnometer, asphalt, and water (plus stopper).

Note: Relative density is also described as specific gravity.

$$Density = relative\ density \times W_T$$

where:

W_T = density of water at the test temperature (see note below)

Note: The density of water from the CRC Handbook of Chemistry and Physics states:

For a temperature of 15.6 °C, there is a density of water of 999.0 kg/m3 (0.990 kg/L); and

For a temperature of 25.0 °C, there is a density of water of 997.0 kg/m3 (0.997 kg/L).

Example Calculations

A = 28.581 g

B = 51.957 g

C = 46.608 g

D = 52.422 g

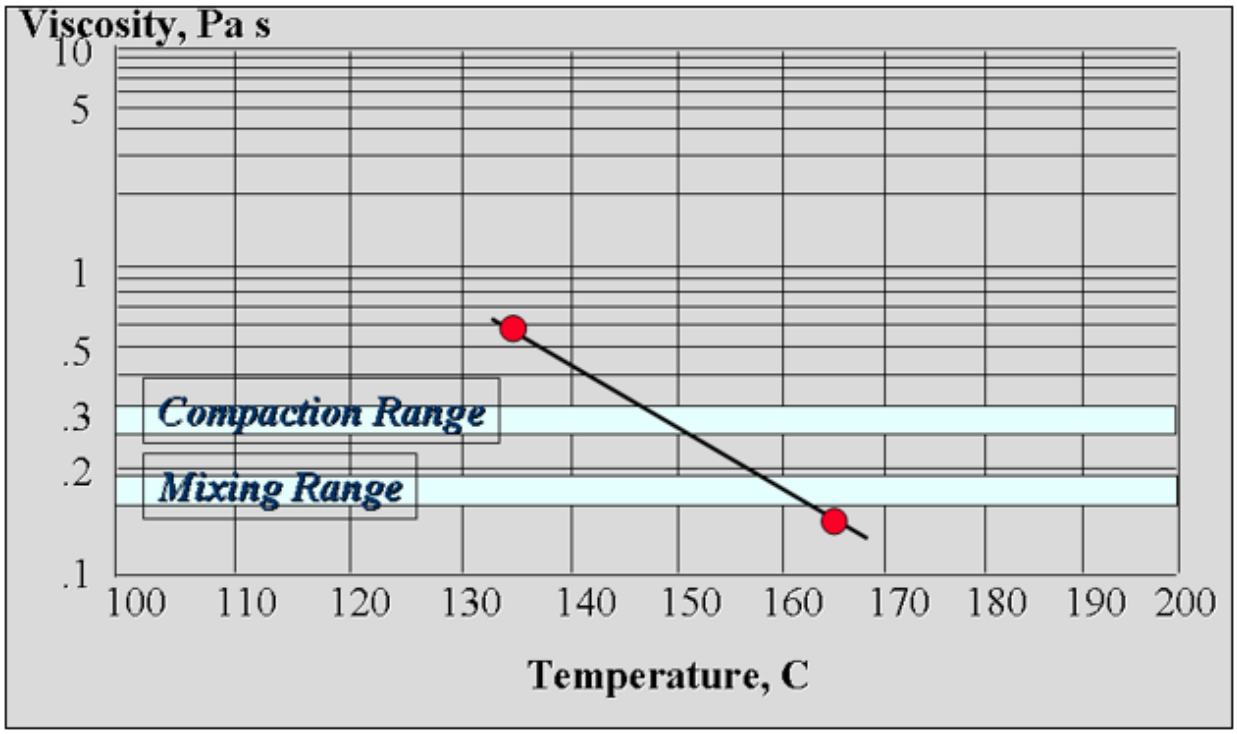
$$\text{relative density} = (\text{C} - \text{A}) \,/\, [(B - A) - (D - C)]$$

$$\text{relative density} = (46.608 - 28.581) \,/\, [(51.957 - 28.581) - (52.422 - 46.608)] = 1.026$$

$$Density = relative\ density \times W_T = 1.026 \times 997.0 = 1023\ kg/m^3 @\ 25.0°C$$

Station 1: AASHTO T316 Rotational Viscosity

Rotational Viscometer Test Results – 135°C			
Viscosity Measurements, taken 1 minute apart, Pa·s			
Average Viscosity for the 3 readings, Pa·s			



The mixing temperature range is defined as the range of temperatures where the unconditioned binder has a viscosity of 0.17 ± 0.02 Pa s.

The compaction temperature is the midpoint of the range of temperatures where the unconditioned binder has a viscosity of 0.28 ± 0.03 Pa s.

Station 2: AASHTO T313 Bending Beam Rheometer

BBR Test Data	
Sample Name:	
Test Temperature:	
Creep Stiffness (s), MPa:	
m-value:	

Station 2: AASHTO T315 Dynamic Shear Rheometer

DSR Test on Original or RTFO-Conditioned Binder	
Original or RTFO-Conditioned?	
Sample Number	
Test Plate Diameter (nearest 0.1 mm)	
Test Gap (nearest 1 µm)	
Test Temperatures (nearest 0.1°C)	
Test Frequency, rad/s	
Strain Amplitude, if strain controlled (nearest 0.01 percent)	
Torque, if stress controlled (nearest mN·m)	
Average Complex Modulus, G^*, for 10 cycles (kPa to three significant figures)	
Average Phase angle, δ, for 10 cycles (nearest 0.1 degrees)	
$G^*/(\sin\delta)$ (nearest 0.01 kPa)	

Station 2: AASHTO T350 Multiple Stress Creep Recovery

MSCR Test on RTFO-Conditioned Binder	
Sample Number	
PG Grade	
Test Temperature	
Average Percent Recovery at 0.1 kPa, $R_{0.1}$	
Average Percent Recovery at 2.2 kPa, $R_{3.2}$	
Nonrecoverable creep compliance at 0.1 kPa, $J_{nr0.1}$, kPa^{-1}	
Nonrecoverable creep compliance at 3.2 kPa, $J_{nr3.2}$, kPa^{-1}	
Percent difference between J_{nr} at 0.1 kPa and 3.2 kPa, J_{nrdiff}	

Station 3: AASHTO R 29 Grading or Verifying the Performance Grade (PG) of an Asphalt Binder

Instructions

Using the M320 Binder Chart, verify the testing data and grade each of the three binders (A, B, and C). Assume change in mass is ≤1.00%.

Example A (Verification)

Binder A, Trial 1 (64-22)			
Binder Type: Original			
Cleveland Flash (ºC)	Flash Point: 306ºC		
Rotational Viscosity @ 135.0ºC (Pa-s)			
1	2	3	AVG
2.275	2.365	2.313	2.318
Dynamic Shear Rheometer			
Test Temp	G*, kPa	Phase Angle, δ	G*/sinδ, kPa
64ºC	0.85	89.0	0.85
Binder Type: RTFO Conditioned			
Dynamic Shear Rheometer			
Test Temp	G*, kPa	Phase Angle, δ	G*/sinδ, kPa
64ºC	2.16	89.0	2.16
Binder Type: PAV Conditioned			
Dynamic Shear Rheometer			
Test Temp	G*, kPa	Phase Angle, δ	G*(sinδ), kPa
25ºC	4988	51.3	3893.0
Bending Beam Rheometer			
Test Temp:			
-12.0°C	Stiffness		286 mPa
	m-value		0.306

Binder A, Trial 2 (58-16)			
Binder Type: Original			
Cleveland Flash (ºC)	Flash Point: 306ºC		
Rotational Viscosity @ 135.0ºC (Pa-s)			
1	2	3	AVG
2.275	2.365	2.313	2.318
Dynamic Shear Rheometer			
Test Temp	G*, kPa	Phase Angle, δ	G*/sinδ, kPa
58ºC	1.04	85.0	1.04
Binder Type: RTFO Conditioned			
Dynamic Shear Rheometer			
Test Temp	G*, kPa	Phase Angle, δ	G*/sinδ, kPa
58ºC	2.24	85.0	2.25
Binder Type: PAV Conditioned			
Dynamic Shear Rheometer			
Test Temp	G*, kPa	Phase Angle, δ	G*(sinδ), kPa
25ºC	5203	51.3	4060.0
Bending Beam Rheometer			
Test Temp:			
-6°C	Stiffness		284 mPa
	m-value		0.303

Example B (Determination)

Binder B, Trial 1 (70-22)			
Binder Type: Original			
Cleveland Flash (ºC)		Flash Point: 288ºC	
Rotational Viscosity @ 135.0ºC (Pa-s)			
1	2	3	AVG
277	284	295	285
Dynamic Shear Rheometer			
Test Temp	G*, kPa	Phase Angle, δ	G*/sinδ, kPa
70ºC	1.20	87.5	1.20
Binder Type: RTFO Conditioned			
Dynamic Shear Rheometer			
Test Temp	G*, kPa	Phase Angle, δ	G*/sinδ, kPa
70°C	2.44	89.0	2.84
Binder Type: PAV Conditioned			
Dynamic Shear Rheometer			
Test Temp	G*, kPa	Phase Angle, δ	G*(sinδ), kPa
28ºC	3944	52.5	3106.7
Bending Beam Rheometer			
Test Temp:			
-12.0°C	Stiffness		255 mPa
	m-value		0.289

Binder B, Trial 2			
Binder Type: Original			
Cleveland Flash (ºC)		Flash Point: 288ºC	
Rotational Viscosity @ 135.0ºC (Pa-s)			
1	2	3	AVG
277	284	295	285
Dynamic Shear Rheometer			
Test Temp	G*, kPa	Phase Angle, δ	G*/sinδ, kPa
????ºC	1.01	89.0	1.01
Binder Type: RTFO Conditioned			
Dynamic Shear Rheometer			
Test Temp	G*, kPa	Phase Angle, δ	G*/sinδ, kPa
????ºC	2.24	89.0	2.24
Binder Type: PAV Conditioned			
Dynamic Shear Rheometer			
Test Temp	G*, kPa	Phase Angle, δ	G*(sinδ), kPa
????ºC	4010	52.1	3871.4
Bending Beam Rheometer			
Test Temp:			
????°C	Stiffness		295 mPa
	m-value		0.301

Original Test Temp: _____

RTFO Conditioned Test Temp: _____

PAV Conditioned (DSR) Test Temp: _____

PAV Conditioned (BBR): Test Temp: _____

Example C (Verify Trial 1, Determine Trial 2)

Binder C, Trial 1			
Binder Type: Original			
Cleveland Flash (ºC)		Flash Point: 225ºC	
Rotational Viscosity @ 135.0ºC (Pa-s)			
1	2	3	AVG
255	255	250	253.3
Dynamic Shear Rheometer			
Test Temp	G*, kPa	Phase Angle, δ	G*/sinδ, kPa
64°C	1.10	88.0	1.10
Binder Type: RTFO Conditioned			
Dynamic Shear Rheometer			
Test Temp	G*, kPa	Phase Angle, δ	G*/sinδ, kPa
64°C	2.24	87.0	2.24
Binder Type: PAV Conditioned			
Dynamic Shear Rheometer			
Test Temp	G*, kPa	Phase Angle, δ	G*(sinδ), kPa
25ºC	4569	52.5	3624.0
Bending Beam Rheometer			
Test Temp:			
-12.0°C	Stiffness		255 mPa
	m-value		0.302

Binder C, Trial 2			
Binder Type: Original			
Cleveland Flash (ºC)		Flash Point: 225ºC	
Rotational Viscosity @ 135.0ºC (Pa-s)			
1	2	3	AVG
255	255	255	255.0
Dynamic Shear Rheometer			
Test Temp	G*, kPa	Phase Angle, δ	G*/sinδ, kPa
70ºC	1.01	89.0	1.01
Binder Type: RTFO Conditioned			
Dynamic Shear Rheometer			
Test Temp	G*, kPa	Phase Angle, δ	G*/sinδ, kPa
70ºC	2.19	89.0	2.18
Binder Type: PAV Conditioned			
Dynamic Shear Rheometer			
Test Temp	G*, kPa	Phase Angle, δ	G*(sinδ), kPa
22ºC	6896	52.1	5441.5
Bending Beam Rheometer			
Test Temp:			
-24°C	Stiffness		295 mPa
	m-value		0.301

Station 4: AASHTO T 48 Flash Point Test

If the barometric pressure differs from 101.3 kPa (760 ± 15 mm Hg), correct the flash point as follows:

$$Corrected\ flash\ point\ = C + 0.25\ (101.3 - K)$$

$$Corrected\ flash\ point\ = F\ + 0.06\ (760 - P)$$

$$Corrected\ flash\ point\ = C + 0.033\ (760 - P)$$

where:

C = observed flash point, °C

F = observed flash point, °F

P = ambient barometric pressure, mm Hg

K = ambient barometric pressure, kPa

Note: The barometric pressure used in these calculations is the ambient pressure for the laboratory at the time of test. Many aneroid barometers, such as those used at weather stations and airports, are pre-corrected to give sea level readings and would not give the correct reading for this test.

Data Sheet

Cleveland Open Cup Flash Point Test Results	
Sample Number	
Observed Flash Point	
Barometric Pressure	
Corrected Flash Point (if necessary)	

Note: The barometric pressure would have to differ from 760 mm Hg by at least 15 mm Hg before the flash point would need to be corrected by even 1°C.

Station 4: AASHTO T 240 Rolling Thin Film Oven

Raw Data

Bottle #1		Bottle #2	
Empty mass of Empty Container #1 (Me,1)	177.1893	**Empty mass of Empty Container #2 (Me,2)**	171.9478
Initial Mass of Sample and Container #1 (Mi,1) =	212.2854	**Initial Mass of Sample and Container #2 (Mi,2) =**	206.7481
Final Mass of Sample and Container #1 (Mf,1)	212.1617	**Final Mass of Sample and Container #2 (Mf,2)**	206.6331

Calculations			
Bottle #1		**Bottle #2**	
$$\%\ change = \frac{(M_i - M_e) - (M_f - M_e)}{(M_i - M_e)} \times 100$$			
Percent Mass Change from Sample Container #1:		Percent Mass Change from Sample Container #2:	
Average Percent Mass Change:			