



# HMEC

Highway Materials Engineering Course

PARTICIPANT WORKBOOK

LABORATORY MANUAL



## Mixture Design



U.S. Department of Transportation  
Federal Highway Administration

MODULE

# F



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## Introduction

Asphalt mixtures, which were once simply a mixture of asphaltic materials and aggregates, now are an ever-evolving combination of asphalt, modifiers, variable aggregate sources, and recycled materials. In addition to the variability in sources of materials and requirements for recycled content and modifiers, there are differences from State to State in how the mixtures are designed with the goals to improve performance, safety, and longevity of the pavements. The most universally accepted design across the country is AASHTO R 35, Standard Practice for Superpave Volumetric Design for Hot Mix Asphalt (HMA). There are many other State-specific design guides that are used throughout the country as well.

## 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)
- Asphalt

### Heat

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.

## Understanding Pressure

Pressure is defined as the force exerted over an area. If you push your finger against a wall, you are exerting pressure. In this case, the pressure is not very strong and you are unlikely to damage the wall. However, if you push a thumbtack against the wall you can make a hole. The force you are using is the same, but the point of the thumbtack is much smaller in area, thus applying a greater pressure.

## Gas Pressure

Often times the pressures used in laboratory work are pressures exerted by a gas. Gas pressure is complex because it is influenced by the volume the gas fills, its temperature, and the amount of gas. For instance, think about a balloon full of air – it is nearly round because the gas inside is pushing with the same force in all directions.

## Units of Pressure

We have already learned that pressure is a measure of the force applied over a specific area. The units for measuring pressure that we used today were invented at various times in history for use in different applications. The International Standard unit of pressure is the Pascal (Pa), which is equal to 1 Newton per square meter. This unit is very small – you're feeling over 100,000 Pa on your skin right now, just from the atmosphere around you. The more commonly used unit is the kilopascal (kPa), which is 1000 times greater than a Pascal.

There are also many older units of pressure that are still in common use, especially in the United States. Pounds per square inch (psi or lb/in<sup>2</sup>) is one of the easiest units to visualize – the atmosphere around you is pushing with a force of approximately 15 pounds on every square inch of your body. Converting between each of the different measurement units is part of what makes working with pressure difficult.

## Measuring in Mercury

The earliest units for pressure were based on the pressure exerted by a column of liquid mercury inside a glass tube, much like the mercury manometers in use today. Mercury (chemical symbol Hg) is a very dense liquid at room temperature and evaporates very slowly, making it ideal for use in measuring pressure. To create the same pressure using water instead of mercury, the column would need to be 13 times taller. Plus, water evaporates readily, and therefore provides inaccurate readings.

U-tube manometers, like those in Figure 1, are often used in laboratory testing. When both ends of the manometer are open, the level of the liquid in the manometer is the same on each side of the tube. The atmosphere is exerting pressure on both sides of the mercury column, and the mercury is in turn exerting pressure back. The system is in equilibrium. In a closed manometer system, air is removed from one end of the tube to create a vacuum. When a vacuum, or negative pressure, is applied to the other end of the system, the mercury is drawn up into the column. The pressure exerted by the mercury remains constant. Since the pressure exerted on the mercury has decreased, the mercury will move up the manometer until a new equilibrium is reached. Conversely, when a positive pressure is applied to the system, the mercury will move up the opposite end of the tube. The difference in height between the two sides of the mercury column can be used to measure the pressure of the system.

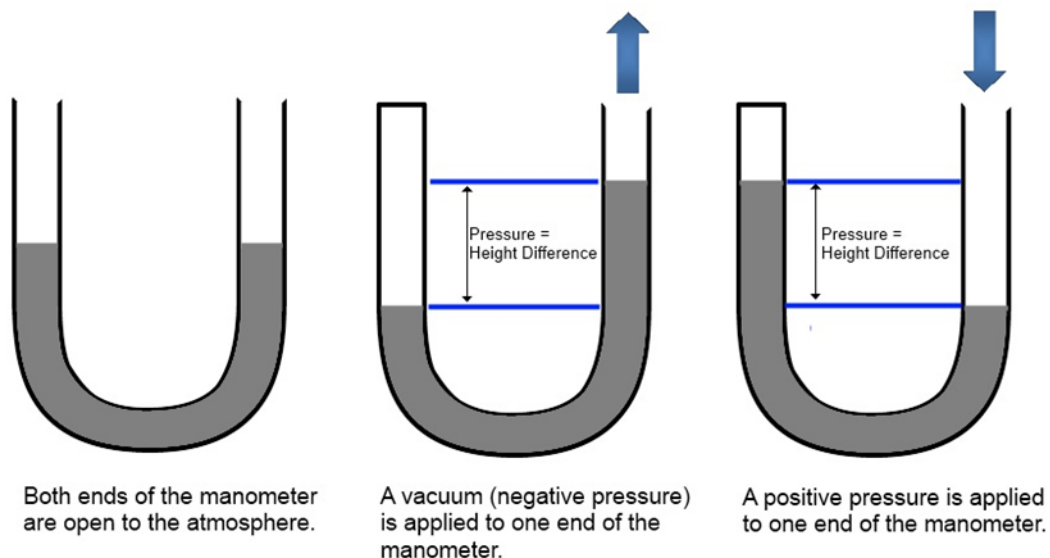


Figure 1: U-tube Manometers

At sea level, the atmosphere exerts sufficient pressure to support a mercury column that is 760 millimeters high. Pressure measurements relative to mercury are still commonly used today. Millimeters of mercury (mm Hg) is still the standard unit for many pressures in medical applications, such as blood pressure. Inches of mercury (in Hg) is a common unit for pressure in laboratory settings. However, many state and local governments have restricted the use of mercury, mostly due to health concerns, and mercury manometers are not always available. Several ways of measuring pressure have been developed that do not rely on mercury.

**Laboratory Testing and Pressure Units**

Multiple systems of measurement can also cause confusion because of the size difference in the units. For example, in the Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt test (commonly called the Rice test, AASHTO T 209) the pressure range required is 25 to 30 millimeters of mercury - a very small range and nearly a vacuum. The pressure range used for saturation of specimens for Resistance of Compacted Hot Mix Asphalt to Moisture-Induced Damage (commonly called the TSR, or Lottman Test, AASHTO T 283) is 10 to 26 inches of mercury - a wide range with lots of room for adjustment. However, these ranges are frequently confused by laboratory personnel because the two tests use similar equipment and the numbers sound similar, even though the units are different. If converted to millimeters of mercury, the range required for the TSR test is 254 to 660 mm Hg, which is quite different than the range required for the Rice test.

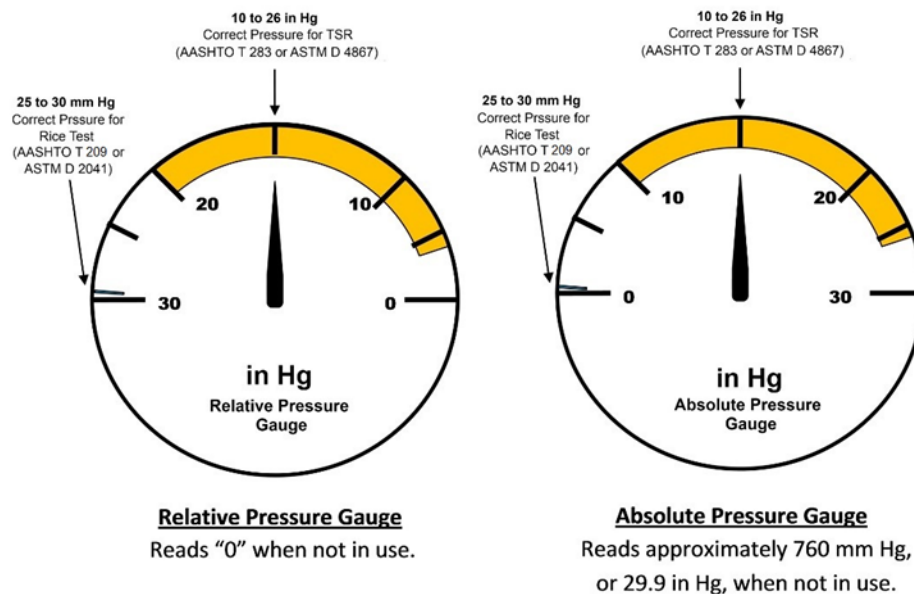


Figure 2: Relative vs. Absolute Pressure



## **Absolute Pressure vs. Relative Pressure**

In addition to the different units, pressure can also be measured from different perspectives. For example, think of a person running a 100-meter dash. You could say the runner has already gone 75 meters or you could say there are 25 meters left to run. Either way is correct, but the answers appear to be different. Pressure poses a similar situation because it can be measured by comparison to atmospheric pressure or to a complete vacuum.

### **Relative Pressure**

Relative pressure is measured “relative” to the pressure created by Earth’s atmosphere. A relative pressure gauge reads “0” when not in use and a positive or negative pressure while in use. Instruments that measure relative pressure are easy to make and less expensive than absolute pressure gauges. So why doesn’t everyone use relative pressure all the time? Unfortunately, relative pressure is not as useful when it comes to calculations for most engineering purposes. Relative pressure changes based on the atmospheric pressure at the time of the measurement, which can vary based on elevation, weather conditions, and several other factors. Relative pressure is useful in some applications, but the more accurate measurement is absolute pressure.

### **Absolute Pressure**

Absolute pressure is measured by comparing the applied pressure to an absolute vacuum, or zero pressure. Absolute pressure doesn’t have to be corrected based on elevation and temperature. Mercury manometers measure absolute pressure. Absolute pressure gauges are usually more expensive than relative pressure gauges, and read approximately 760 mm Hg (or atmospheric pressure) at sea level when they are not in use.

### **Working with Vacuum**

In construction materials testing, many test methods require the application of vacuum. Applying a vacuum means creating negative pressure, so that the pressure inside the container is less than the pressure created by the atmosphere. Test methods often direct you to “increase the vacuum,” which is the same as decreasing the pressure in the container.

Because of their low cost, relative pressure gauges are sometimes used for tests that specify absolute pressure measurement. In this case, the pressure readings must be converted from a relative pressure reading to an absolute pressure measurement.

## **Barometric Pressure and Adjusting for Altitude**

Barometric pressure is the same as atmospheric pressure – it is the pressure of the air around you at the time the reading is taken. Barometric pressure varies based on altitude and temperature. If you are at sea level, you are feeling about 14.7 psi on your skin from the atmosphere around you. However, if you are in mile-high Denver, Colorado, the pressure is only about 12 psi. If you hike up into the mountains outside of Denver, the pressure might go down to just 8.5 psi. Not many people build laboratories on top of mountains, but clearly the change in barometric pressure can make a big difference in test results, especially when using a relative pressure gauge. The pressure used in the degassing oven described above should be adjusted for local barometric pressure conditions so that the absolute pressure used is  $15 \pm 5$  kPa.

## **Other Terms**

There are plenty of other terms for pressure besides relative, absolute, and barometric. Residual pressure is the pressure remaining in a container after you apply a vacuum. It's the pressure that is "left over," hence the name. Partial pressure, used in many engineering activities, is the pressure applied by just one gas in a mixture of gases. The partial pressure of oxygen is an important number for scuba divers when monitoring their breathing equipment.

### Laboratory Procedures and Time Needed to Complete

<b>Standard Designation</b>	<b>Test Name</b>	<b>Total Time</b>	<b>Hands-on Time</b>
<b>AASHTO R 47</b>	Standard Practice for Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size	2 hours, 30 minutes	30 minutes
<b>AASHTO T 166</b>	Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface-Dry Specimens	8 hours, 5 minutes	5 minutes
<b>AASHTO T 209</b>	Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt	4–5 hours	30 minutes
<b>AASHTO T 269</b>	Percent Air Voids in Compacted Dense and Open Asphalt Mixtures	1 minute	1 minute
<b>AASHTO T 283</b>	Standard Method of Test for Resistance of Compacted Hot Mix Asphalt (HMA) to Moisture-Induced Damage	4 days	1 hour
<b>AASHTO T 312</b>	Preparing and Determining the Density of Hot Mix Asphalt (HMA Specimens by Means of the Superpave Gyratory Compactor)	1 hour	1 hour
<b>AASHTO T 331</b>	Bulk Specific Gravity (Gmb) and Density of Compacted Hot Mix Asphalt (HMA) Using Automatic Vacuum Sealing Method	8 hours	25 minutes
<b>AASHTO T 308</b>	Standard Method of Test for Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Oven	7 hours	30 minutes

## **AASHTO R 47, Standard Practice for Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size**

### **Background Information**

Reducing samples, commonly referred to as “splitting,” is the process of reducing large samples of asphalt mixtures to smaller yet representative sizes for testing. It is essential to minimize any variations in the measured characteristics between the test samples and the original, larger sample.

### **Significance and Use**

Specifications for asphalt mixtures require sampling portions of the material for testing. It is essential to select a portion of the larger sample, which is representative of the total supply of HMA for testing. This method provides procedures for reducing the large sample obtained in the field or produced in the laboratory to a convenient size for conducting a number of tests. These tests determine the characteristics of the test sample portion and thus of the total supply. The minimum quantity of material necessary is provided in the individual test methods.

### **Related Tests and Specifications**

- AASHTO T 168, Sampling Bituminous Paving Mixtures

### **Timeline for Completion**

Prep Time: 2 hours

Prior to splitting, the sample shall be warmed to a workable condition.

Time to Perform Procedure: 30 minutes

Sample is reduced in size to the desired test mass utilizing one of the three prescribed methods.

TOTAL TIME: 2 hours, 30 minutes

### **Apparatus**

Mechanical Splitter Method (requires either a Type A or a Type B splitter):

- Mechanical Splitter Type A – Commonly referred to as the “quartermaster,” this splitter will allow the material to be split into four equal samples.

- Mechanical Splitter Type B – The splitter must have an equal number of chutes that discharge in opposite directions.
- Asphalt Release Agent – Optional. An approved release agent that does not contain any solvents or petroleum-based products that could affect asphalt binder properties.

**Note: It is recommended that for a large amount of material, a mechanical splitter should be used whenever possible. This will lessen the time needed for reduction and help minimize the loss of heat.**

Quartering Method:

- Quartering Template – A template made of suitable material and with sides which form a 90-degree angle at their juncture.
- Flat Bottom Scoop
- Straightedge
- Non-stick Paper – Or heat-resistant plastic.
- Asphalt Release Agent (optional) – An approved release agent that does not contain any solvents or petroleum-based products that could affect asphalt binder properties.

**Note: Non-stick cooking spray has been found to be an acceptable release agent.**

Incremental Method:

- Flat Bottom Scoop
- Non-stick Heavy Paper – Or heat-resistant plastic.
- Large Spatulas – Or trowels, metal straightedge, or drywall knife.
- Miscellaneous Equipment – Hot plate, gloves, pans, buckets, and cans.

### **Procedure for Mechanical Splitter Method**

Place the splitter on a level surface. If desired, heat the splitter and accessory equipment, but not over 110 °C (230 °F). Also if desired, apply a light coat of a release agent on any surface that comes in contact with the HMA. These two steps can limit the amount of material that sticks to the surfaces and minimizes the loss of asphalt binder and fines.

#### **Mechanical Splitter Type A**

##### **Step 1**

Position a sample container under each of the four chutes to collect the reduced portions of the sample.

**Step 2**

Place the sample into the hopper from multiple directions. This step will help avoid segregation of the sample.

**Step 3**

Pull the handle to drop the material through the dividers into the sample containers.

**Step 4**

Discard the material from two buckets in opposite corners. Repeat this process, using the material that was not discarded, as many times necessary until the desired sample size is obtained.

**Mechanical Splitter Type B****Step 1**

Place the sample of HMA into the sample splitter pan or hopper and spread evenly from edge to edge. This will ensure that approximately equal amounts of material will flow through each chute.

**Step 2**

Slowly introduce the sample into the hopper so the material is able to flow freely into the sample containers.

**Step 3**

Discard the material in one container. Repeat this process until the desired sample size is obtained.

**Procedure for Quartering Method****Step 1**

Place the sample on a level surface. A release agent may be applied to the working surface.

**Step 2**

Mix the sample thoroughly by turning the sample over four times or by lifting each corner of the paper four times.

**Step 3**

Create a pile of material in the center of the work area.

**Step 4**

Flatten the pile to a uniform thickness and diameter by pressing down on the top of the pile with the flat-bottomed scoop.

**Step 5**

The diameter of the pile should be approximately four to eight times its thickness.

**Step 6**

Press the quartering template down into the middle of the sample to create four equal sections.

**Step 7**

Discard material from opposite corners and continue the process until the desired sample size is obtained.

**Procedure for Incremental Method****Step 1**

Place the sample on non-stick heavy paper.

**Step 2**

Mix the sample thoroughly by turning the sample over four times or by lifting each corner of the paper.

**Step 3**

Create a pile with the material in the center of the paper.

**Step 4**

Roll the material in the paper into a cylindrical roll or “loaf” and flatten the top.

**Step 5**

Pull the paper so at least one-fourth of the length of the loaf is off the edge of the counter. Allow this material to drop into a container or slice the loaf with a straightedge. Set this material aside.

**Step 6**

Continue to remove additional material until the desired sample size is obtained.

**Note: Material discarded during the splitting process can be retained and used for other testing after splitting down to the appropriate test size.**

**Common Errors**

- Handling of material should be limited to eliminate segregation of the material.
- Use of unapproved release agents may result in material composition changes.

## **AASHTO T 166, Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface-Dry Specimens**

### **Background Information**

This test procedure determines the bulk specific gravity of compacted bituminous mixtures. This method is not for use with stone matrix asphalt (SMA) and open graded asphalt (OGA) mixes.

### **Significance and Use**

The results from this test are most commonly used in conjunction with the results obtained from AASHTO T 209, Theoretical Maximum Specific Gravity of Hot Mix Asphalt. These values are the two components needed to calculate the percent air voids present in compacted bituminous mixtures, a critical tool for evaluating the compaction achieved in asphalt paving projects, as well as mix design determination.

### **Related Tests and Specifications**

- AASHTO T 209, Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt
- AASHTO T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
- AASHTO T 331, Bulk Specific Gravity and Density of Compacted Hot Mix Asphalt Using Automatic Vacuum Sealing Method
- AASHTO T 275, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens

### **Timeline for Completion**

Prep Time: 8 hours (or less)

Field specimens must be dried to a constant mass. Depending on the amount of moisture present, overnight drying may be required. Laboratory compacted specimens do not require drying.

Time to Perform Procedure: 5 minutes

Determine the dry mass of the specimen. Place the dry specimen in a water bath for 3–5 minutes. Determine the mass in water. Quickly blot the specimen with a damp towel, and obtain a final mass.

Calculations: 1 minute



Calculate the bulk specific gravity and absorption.

TOTAL TIME: 8 hours

### Apparatus

**Balance** – Must be of sufficient capacity, readable to 0.1% of the sample mass or better, and equipped with a suitable suspension apparatus for weighing suspended specimens.

**Suspension Apparatus** – The wire suspending the specimens shall be of the smallest diameter possible and the bath shall completely immerse the suspension apparatus without allowing entrapped air underneath the specimen.

**Water Bath** – For immersing the specimen in water while suspended from the balance, it shall be equipped with an overflow outlet to maintain a constant water level during testing. See Figure 3. Test temperature of the water should be  $25 \pm 1$  °C.



Figure 3: Water bath

### Sample Preparation

Cored specimens shall be dried to a constant mass at a temperature of  $52 \pm 3$  °C. Recently compacted laboratory specimens do not require drying. Cool the specimen to room temperature.

### Procedure

#### Step 1

Record the dry mass of the specimen (A).

**Step 2**

Immerse the specimen in the water bath at  $25 \pm 1$  °C for  $4 \pm 1$  minutes. Record the immersed mass (C). See Figure 4.



*Figure 4: Specimen in water bath*

**Step 3**

Remove the specimen from the bath. Rapidly blot free moisture from the specimen using a damp towel. Removal from the bath, blotting, and massing of the specimen should not exceed 15 seconds.

**Step 4**

Immediately weigh the saturated surface dry specimen. Record the saturated-surface-dry (SSD) mass (B).

**Calculations****Step 1**

Calculate the bulk specific gravity as follows:

$$\frac{A}{B - C}$$

Where:

$A$  = mass of specimen in air, g

$B$  = mass of the surface dry specimen in air, g

$C$  = mass of the specimen in water, g

### Step 2

Calculate the percent of water absorbed by the specimen as follows:

$$\frac{B - A}{B - C} \times 100$$

### Step 3

If the percent of water absorbed by the specimen is greater than 2.0%, this method is invalid and either T 275 or T 331 should be used to determine the bulk specific gravity.

### Example Calculations

Table 1

Dry weight (A)	1,261.2 g
SSD weight (B)	1,263.2 g
Weight in water (C)	749.1 g
Bulk specific gravity (A/[B-C])	2.453
Percent of water absorbed ([B-A] / [B-C]) X 100	.39%

### Reporting the Test Results

Report the bulk specific gravity to the nearest thousandth. Report the percent water absorbed to the nearest hundredth.

### Common Errors

- The towel used to blot the specimen must be damp. The towel is considered damp when no water can be wrung from it.
- The mass of the basket in water is not zeroed prior to immersing the specimen in the bath.
- The temperature of the water bath is outside of the required tolerance.

- The percent water absorbed was not calculated.

### Data Sheet

Dry weight (A), g	
SSD weight (B), g	
Immersed weight (C), g	
Bulk specific gravity $\frac{A}{B-C}$	
Percent water absorbed $\frac{B-A}{B-C} \times 100$	

### Alternate Methods

**Method B** – Uses a volumeter to weigh the sample in air as a replacement to the underwater weighing in method A.

**Method C** – Used for samples that are not required to be saved and contain a substantial amount of moisture. The procedure is the same except for the dry mass determination.

## **AASHTO T 209, Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt**

### **Background Information**

This test procedure determines the maximum specific gravity of uncompacted bituminous mixtures and is commonly known as the Rice test, named for its inventor James Rice.

### **Significance and Use**

The results from this test are most commonly used in conjunction with the results from AASHTO T 166, Bulk Specific Gravity of Compacted Hot Mix Using Saturated Surface-Dry Specimens. These values are the two components needed to calculate the percent air voids present in compacted bituminous mixtures, a critical tool for evaluating the compaction achieved in asphalt paving projects, as well as mix design determination.

### **Related Tests and Specifications**

- AASHTO M 231, Weighing Devices Used in the Testing of Materials
- AASHTO T 166, Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface-Dry Specimens
- AASHTO T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
- AASHTO T 331, Bulk Specific Gravity and Density of Compacted Hot Mix Asphalt Using Automatic Vacuum Sealing Method

### **Timeline for Completion**

Prep Time: 3–4 hours

Laboratory prepared specimens must be cured for 2 hours. Plant mixed samples must be dried to a constant mass. As the material cools, the particles are separated by hand such that no conglomerates are larger than 0.25 in. Allow the particles to cool to room temperature.

Time to Perform Procedure: 30 minutes

Cover the loose hot mix with room temperature water. Apply a vacuum of  $27.5 \pm 2.5$  mm Hg for  $15 \pm 2$  minutes. Weigh the sample either in water in or in air after reaching thermal equilibrium in a water bath.

Calculations: 2 minutes

Calculate the theoretical maximum specific gravity.

TOTAL TIME: 4–5 hours

### Apparatus

**Vacuum Container** – Typically made of metal, the hose end connecting the container to the vacuum pump must be covered with a piece of mesh to prevent the loss of fines. The diameter should be approximately 7-10 in. with a minimum height of 6.3 in., equipped with a transparent lid.

**Note: Vacuum vessels come in many forms: metal cylinders (most common), 4,000-mL flasks, plastic bowls, etc. The vessel also goes by a variety of names: Rice pot, vacuum bowl, pycnometer, etc.**

**Mechanical Shaker (optional)** – A vibrating table to aid in removal of entrapped air. See Figure 5.



*Figure 5: Mechanical shaker*

**Balance** – G2, meeting the requirements of M 231.

**Vacuum Pump** – Capable of achieving a pressure of 30 mm Hg absolute. The pump shall be protected by a series of traps, connected in line between the vacuum vessel and the vacuum source.

**Vacuum Measurement Device** – Manometer (Figure 6) or pressure gauge (Figure 7), calibrated annually, accurate to 1 mm Hg. Must be connected directly to the vacuum vessel.



Figure 6: Manometer



Figure 7: Digital pressure gauge

**Bleeder Valve** – Facilitates the fine adjustment of the pressure in the vessel.

**Thermometer** – Readable to 0.5 °C.

**Water Bath** (if weighing in water) – Maintained at  $25 \pm 1$  °C, must be of suitable size and equipped with a suspension apparatus.

**Drying Oven**

**Sample Preparation**

Minimum sample masses must meet the requirements of Table 2.

Table 2: Sample Size

Nominal Maximum Aggregate Size, mm	Minimum Sample Size, g
37.5 or greater	4,000
19 to 25	2,500
12.5 or smaller	1,500

Separate the warm hot mix asphalt particles by hand, taking care to not fracture any aggregates. Conglomerates larger than 0.25 in. shall be reduced to a smaller size. If a field sample is used, dry the sample to a constant mass. If a laboratory sample is used, cure the loose mix at  $135 \pm 5$  °C for 2 hours. Cool the sample to room temperature. Place in the vacuum vessel and record this mass as A. Cover the sample completely with water at approximately 25 °C.

### Procedure – Standardization of the Vessel, Weighing in Water

#### Step 1

Suspend the vessel in the water bath at  $25 \pm 1$  °C.

#### Step 2

Record the weight in water as B.

### Procedure – Standardization of the Vessel, Weighing in Air

#### Step 1

Fill the vessel to its calibrated capacity with water at  $25 \pm 1$  °C. A glass plate or pycnometer lid should be used to ensure accurate measurement.

#### Step 2

Completely dry the outside of the vessel. Record the weight of the vessel and water as D.

### Procedure – Method A, Mechanical Agitation (Shaker Required)

#### Step 1

Place the vessel on the mechanical shaker. Remove all air entrapped in the loose hot mix sample by applying a vacuum to the vessel. Increase pressure gradually until the manometer reads  $27.5 \pm 2.5$  mm Hg absolute.

#### Step 2

Maintain  $27.5 \pm 2.5$  mm Hg absolute for a period of  $15 \pm 2$  minutes. The shaker table should be turned on and allowed to vibrate for the duration.



**Step 3**

Gradually release the pressure at a rate not to exceed 8 kPa/second (60 mm Hg/second).

**Step 4**

Perform one of the following mass determinations.

**Procedure – Method B, Manual Agitation****Step 1**

Remove all air entrapped in the loose hot mix sample by applying a vacuum to the vessel. Increase pressure gradually until the manometer reads  $27.5 \pm 2.5$  mm Hg absolute.

**Step 2**

Maintain  $27.5 \pm 2.5$  mm Hg absolute for a period of  $15 \pm 2$  minutes. Agitate the container vigorously by shaking at 2-minute intervals.

**Step 3**

Gradually release the pressure at a rate not to exceed 8 kPa/second (60 mm Hg/second).

**Step 4**

Perform one of the following mass determinations.

**Note: When comparing results, the length and level of effort of manual agitation can increase differences in test results.**

**Procedure – Mass Determination, Weighing in Water****Step 1**

Suspend the container and contents in a water bath at  $25 \pm 1$  °C and allow the temperature to stabilize for  $10 \pm 1$  minute.

**Step 2**

Record the in water mass as C.

**Procedure – Mass Determination, Weighing in Air****Step 1**

Fill the vacuum vessel to its calibrated capacity with water at  $25 \pm 1$  °C.

**Step 2**

Within  $10 \pm 1$  minute after the vacuum being removed, weigh the vessel and record this mass E.

### Calculations, Weighing in Water

Calculate the theoretical maximum specific gravity ( $G_{mm}$ ):

$$\frac{A}{A - (C - B)}$$

Where:

$A$  = weight of the oven-dry sample in air, g or lb.

$B$  = weight of the vessel in water, g or lb.

$C$  = weight of the sample in water, g or lb.

Calculate the theoretical maximum density:

Max density = Max specific gravity X 997.1 kg/m<sup>3</sup> (or 62.2 lb./ft<sup>3</sup>)

### Example Calculations, Weighing in Water

Dry weight of sample, $A$	2,067.4 g
Weight of the vessel in water, $B$	1,505.8 g
Weight of the sample in water, $C$	2,853.0 g
Max specific gravity, $G_{mm}$	2.871
Maximum density, kg/m <sup>3</sup>	2,862.3 kg/m <sup>3</sup>

### Calculations, Weighing in Air

Calculate the theoretical maximum specific gravity ( $G_{mm}$ ):

$$\frac{A}{A + D - E}$$

Where:

$A$  = weight of the oven-dry sample in air, g or lb.

$D$  = weight of the vessel filled to its calibrated capacity with water, g or lb.

$E$  = weight of the vessel with sample, filled to the calibrated capacity with water, g or lb.

Calculate the theoretical maximum density:

Max density = Max specific gravity X 997.1 kg/m<sup>3</sup> (or 62.2 lb./ft<sup>3</sup>)

### Example Calculations, Weighing in Air

Dry weight of sample, <i>A</i>	1,520.1 g
Weight of the vessel in water, <i>B</i>	8,232.8 g
Weight of the sample in water, <i>C</i>	9,187.0 g
Max specific gravity, $G_{mm}$	2.686
Maximum density, kg/m <sup>3</sup>	2,678.2 kg/m <sup>3</sup>

### Reporting the Test Results

The report should include the following:

- Maximum specific gravity ( $G_{mm}$ ) to the nearest 0.001
- Type of hot mix tested
- Size of the sample, number of samples
- Type of container used and Test method used

### Common Errors

- Vacuum system is not set up correctly.
- Temperature is not allowed to stabilize for  $10 \pm 1$  minutes.
- Water bath is not maintained at  $25 \pm 1$  °C.
- Calculations are performed incorrectly.

**Data Sheets**

Dry weight of sample, $A$	
Weight of the vessel in water, $B$	
Weight of the sample in water, $C$	
Max specific gravity, $G_{mm}$	
Maximum density, $\text{kg/m}^3$	

**Weighing in Air**

Dry weight of sample, $A$	
Weight of the vessel filled with water, $D$	
Weight of the sample, water, and vessel, $E$	
Max specific gravity, $G_{mm}$	
Maximum density, $\text{kg/m}^3$	

**Alternate Methods**

There is a supplemental method for mixtures containing aggregate with a water absorption above 1.5%

## **AASHTO T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures**

### **Background Information**

This test calculates the percentage of air voids present in a compacted asphalt sample. The bulk specific gravity result from AASHTO T 166, T 275, or T 331 (if open-graded mixtures are tested), and the theoretical maximum specific gravity result from T 209 are the two values needed to perform the percent air voids calculation.

### **Significance and Use**

Air voids are a crucial design component of asphalt mixtures. Air voids affect the durability and stability of the final product, and mix design criteria specify specific air void requirements for paving mixtures.

### **Related Tests and Specifications**

- AASHTO T 166, Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface Dry Specimens.
- AASHTO T 209, Theoretical Maximum Specific Gravity of Asphalt
- AASHTO T 275, Bulk Specific Gravity of Compacted Hot Mix Asphalt (HMA) Using Paraffin-Coated Specimens
- AASHTO T 331, Bulk Specific Gravity and Density of Compacted Hot Mix Asphalt Using Automatic Vacuum Sealing Method

### **Timeline for Completion**

Calculations: 1 minute

Calculate percent air voids.

TOTAL TIME: 1 minute

### **Calculations**

$$\text{Air voids} = (1 - A/B) \times 100$$

Where:

$A$  = bulk specific gravity

$B$  = maximum specific gravity

Report the air voids to the nearest 0.1

### Example

<b>Bulk specific gravity (from T 166)</b>	2.377
<b>Maximum specific gravity (from T 209)</b>	2.504
<b>Air voids</b>	5.1%

### Data Sheet

Bulk specific gravity (from T 166)	
Maximum specific gravity (from T 209)	
Air voids	

## **AASHTO T 283, Standard Method of Test for Resistance of Compacted Hot Mix Asphalt (HMA) to Moisture-Induced Damage**

### **Background Information**

Specimens for each of the mix conditions, such as specimens prepared with untreated asphalt binder, asphalt binder treated with anti-stripping agent, or aggregate treated with lime, are prepared and subjected to accelerated moisture conditioning. The specimens are then tested for indirect tensile strength. Indirect tensile strength tests are also performed on a dry subset of specimens for comparison. The test is sometimes called the TSR (short for tensile strength ratio), or the Lottman test.

### **Significance and Use**

This method is intended to evaluate the effects of saturation and accelerated water conditioning on compacted asphalt mixtures. One subset of specimens will be tested dry, and the other subset will be tested after accelerated water conditioning (partial vacuum saturation, freezing, and soaking in warm water).

(Note: Freezing of the “wet” subset of specimens is a mandatory step in the water conditioning process. It is not related to any climatic conditions but is simply meant to accelerate the process.)

The ratio of the strength of samples subjected to accelerated water conditioning to the strength of samples of the dry subset is called the tensile strength ratio (TSR).

### **Related Tests and Specifications**

- AASHTO T 166, Bulk Specific Gravity (G<sub>mb</sub>) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
- AASHTO T 209, Theoretical Maximum Specific Gravity (G<sub>mm</sub>) and Density of Hot Mix Asphalt (HMA)
- AASHTO T 269 Percent Air Voids in Compacted Dense and Open Asphalt Mixtures

### **Timeline for Completion**

Prep Time: Approximately 2 days

Laboratory-mixed samples must be conditioned before and after compaction.

Time to Perform Procedure: Approximately 2 days

Compacted samples are saturated by use of a vacuum. The conditioned subset shall be subjected to a freeze-thaw cycle for specific times. Samples are then tested.

Active Testing Time: 1 hour

Calculations: 30 minutes

Calculate the tensile strength and tensile strength ratio.

TOTAL TIME: Approximately 4 days

## Apparatus

**Compaction Equipment** – The sample may be compacted by use of one of the following methods: AASHTO T 245, AASHTO T 247, AASHTO T312, or ASTM D3387.

**Vacuum Apparatus** – Equipment for determining the theoretical maximum specific gravity (Gmm) of the sample from AASHTO T 209 or ASTM D2041.

**Balance** – Must be of sufficient capacity, readable to 0.1% of the sample mass or better, and equipped with a suitable suspension apparatus for weighing suspended specimens.

**Water Bath(s)** – A bath capable of maintaining a temperature of  $60 \pm 1^\circ\text{C}$  ( $140 \pm 1.82^\circ\text{F}$ ) and a bath capable of maintaining a temperature of  $25 \pm 0.5^\circ\text{C}$  ( $77 \pm 1^\circ\text{F}$ )

**Freezer** – maintained at  $-18 \pm 3^\circ\text{C}$  ( $0 \pm 5^\circ\text{F}$ ).

**Plastic Film** - Used for wrapping specimens; heavy-duty, leak-proof plastic bags to enclose the saturated specimens, and masking tape.

**Note: Saran Wrap® or an equivalent material can be used for wrapping specimens.**

### 10-mL Graduated Cylinder

### Pans of Sufficient Size

**Oven** – Forced air draft and capable of maintaining any desired temperature setting from room temperature to  $176^\circ\text{C}$  ( $350^\circ\text{F}$ ).

**Testing Apparatus** – Loading jack and ring dynamometer conforming to AASHTO T 245, or a mechanical or hydraulic testing machine conforming to AASHTO T 167 that provides a vertical deformation rate of 2 in./min (50 mm/min).



**Loading Strips** – Made of steel with a concave surface having a radius of curvature equal to the nominal radius of the test specimen and a width of 0.5 in. for a 4-in. diameter specimen or 0.75 in. for a 6-in. diameter specimen.

### **Preparation of Specimens**

Specimens can be prepared by mixing and compacting material in the laboratory, compacting field-mixed (plant) material in the laboratory, or obtaining cores from a road and sawing them.

### **Preparation of Laboratory-Mixed, Laboratory-Compacted Specimens**

#### **Step 1**

Cool mixed samples at room temperature for  $2 \pm 0.5$  hours, then place in a  $60 \pm 3$  °C ( $140 \pm 5$  °F) oven for a  $16 \pm 1$  hours to cure.

#### **Step 2**

After curing, place the mixture in an oven for 2 hours  $\pm$  10 minutes at the compaction temperature.

#### **Step 3**

Compact the specimens to  $7.0 \pm 0.5\%$  air voids using either AASHTO method T 245 (Marshall), T 247 (California Kneading Compactor), T 312 (Superpave Gyrotory Compactor), or ASTM D3387 (US Corps of Engineers Gyrotory Testing Machine).

**Note: It may be necessary to adjust the number of blows in T 245; adjust the foot pressure, number of tamps, leveling load, or some combination in T 247; or adjust the number of revolutions in T 312 or ASTM D3387, in order to achieve the 7% air voids. This should be done experimentally for each mixture before compacting the specimens.**

#### **Step 4**

Remove the specimens from the molds and store at room temperature for  $24 \pm 3$  hours.

### **Preparation of Field-Mixed, Laboratory-Compacted Specimens**

#### **Step 1**

Sample field-mixed asphalt mixtures in accordance with ASTM D979 and then obtain the desired sample size from the sample by splitting in accordance with AASHTO R 47.

#### **Step 2**

Heat the mixture in an oven until it reaches the compaction temperature.

**Step 3**

Compact the specimens to  $7.0 \pm 0.5\%$  air voids using either AASHTO method T 245 (Marshall), T 247 (California Kneading Compactor), T 312 (Superpave Gyratory Compactor), or ASTM D3387 (US Corps of Engineers Gyratory Testing Machine).

**Step 4**

Remove the specimens from the molds and store at room temperature for  $24 \pm 3$  hours.

**Note: It may be necessary to adjust the number of blows in T 245; adjust the foot pressure, number of tamps, leveling load, or some combination in T 247; or adjust the number of revolutions in T 312 or ASTM D 3387, in order to achieve the 7% air voids. This should be done experimentally for each mixture before compacting the specimens.**

**Preparation of Field-Mixed, Field-Compacted Specimens (Cores)****Step 1**

Obtain core samples and separate the layers (as necessary) by sawing them, or by other suitable means.

Note: There is no loose-mix curing or compacted-mix curing for cores.

**Step 2**

Store the layers at room temperature until they are dry.

**Evaluation and Grouping (Wet Versus Dry) of Specimens****Step 1**

Determine the theoretical maximum specific gravity ( $G_{mm}$ ) of a representative sample of the asphalt mixture.

**Step 2**

Determine the thickness ( $t$ ) and diameter ( $D$ ) of each compacted specimen or core.

**Step 3**

Determine the bulk specific gravity ( $G_{mb}$ ) of each compacted specimen or core. Express the volume ( $E$ ) of each specimen (the SSD mass of the specimen minus the mass of the specimen in water) in cubic centimeters.

**Step 4**

Calculate the percentage of air voids ( $P_a$ ).

**Step 5**

Separate the compacted specimens into two groups, with at least three specimens in each group, so that average air voids of the two groups are approximately equal.

**Step 6**

For the specimens designated as the “wet” group, calculate the volume of air voids ( $V_a$ ) in each specimen, in cubic centimeters, using the following equation:

$$V_a = \frac{P_a E}{100}$$

Where:

$V_a$  = volume of air voids,  $\text{cm}^3$

$P_a$  = air voids, percent

$E$  = volume of specimen,  $\text{cm}^3$

**Preconditioning of Test Specimens**

**Dry group:**

*Step 1*

Wrap each specimen with plastic or place in a heavy-duty, leak-proof plastic bag. Place the specimens in a 25 °C (77 °F) water bath for 2 hours  $\pm$  10 minutes. Ensure that the specimens are covered with at least 1 in. of water.

*Step 2*

Determine the indirect-tensile strength as described in the Testing section.

**Note: The dry samples come should come from the same water bath as the wet samples just prior to breaking. If there is a temperature differential from two different water baths, the variability will increase.**

**Conditioned (wet) group:**

*Step 1*

Partially saturate and determine the degree of saturation of each specimen by performing the following steps (one specimen at a time):

Place the specimen in a vacuum container with a perforated spacer on the bottom to allow for at least 1 in. of space between the vessel and the specimen.

*Step 2*

Fill the container with room temperature water until the specimen is covered by at least 1 in. of water.

*Step 3*

Apply a vacuum of 13 to 67 kPa absolute pressure (10 to 26 in. Hg partial pressure) for a short time. Remove the vacuum and keep the specimen in the water for a short period of time.

**Note: The time the vacuum should be applied and the time the specimen should be left submerged after vacuuming shall be approximately 5 to 10 minutes.**

*Step 4*

Determine the mass of the SSD specimen ( $B'$ ).

*Step 5*

Calculate the volume of absorbed water ( $J'$ ) in cubic centimeters with the following equation:

$$J' = B' - A$$

Where:

$J'$  = volume of absorbed water,  $\text{cm}^3$

$B'$  = mass of the SSD specimen after partial vacuum saturation, g

$A$  = mass of the dry specimen in air, g

*Step 6*

Determine the degree of saturation ( $S'$ ) by comparing the volume of absorbed water ( $J'$ ) with the volume of air voids ( $V_a$ ) using the following equation:

$$S' = \frac{100J'}{V_a}$$

$S'$  = degree of saturation, percent

- If the degree of saturation is between 70 and 80%, proceed to the next step.
- If the degree of saturation is less than 70%, then repeat the vacuum saturation procedure using more vacuum or time.
- If the degree of saturation is more than 80%, the specimen must be discarded.

**Note: The vacuum pressure and time is less important than achieving 70-80% saturation. If the specimen is saturating too quickly, reduce the pull of the vacuum system. Check to make sure that 10 to 26 in. Hg relative (partial) pressure is being applied, not the 25 mm Hg absolute pressure that is specified for the maximum specific gravity (Rice) test. A standard U-bend mercury manometer may not register a reading at the correct pressure for this test, so be sure to use a gauge with the correct range.**

*Step 7*

Wrap each specimen with plastic film and place in a plastic bag with  $10 \pm 0.5$  mL of water and then seal the bag.

*Step 8*

Place the specimens in a freezer at  $-18\text{ }^{\circ}\text{C}$  ( $0\text{ }^{\circ}\text{F}$ ) for a minimum of 16 hours.

Note: Freezing of the “wet” subset of specimens is a mandatory step in the water-conditioning process. It is not related to any climatic conditions but is simply meant to accelerate the process.

*Step 9*

Remove the specimens from the freezer and place in a  $60\text{ }^{\circ}\text{C}$  ( $140\text{ }^{\circ}\text{F}$ ) water bath for  $24 \pm 1$  hours. As soon as possible during this time, remove the plastic bag and wrap from each specimen.

*Step 10*

Remove the specimens and place them in a water bath at  $25\text{ }^{\circ}\text{C}$  ( $77\text{ }^{\circ}\text{F}$ ) for  $2\text{ hours} \pm 10\text{ minutes}$ .

Note: It may be necessary to add ice to the water bath to prevent the water temperature from rising above  $25\text{ }^{\circ}\text{C}$  ( $77\text{ }^{\circ}\text{F}$ ).

*Step 11*

Remove the specimens from the bath.

## Testing

**Step 1**

Determine the thickness ( $t'$ ) of each specimen.

**Step 2**

Place the specimen between the steel loading strips (Figure 8).



*Figure 8: Specimen between the steel loading strips*

**Step 3**

Place the specimen and loading strips between the two plates in the testing machine.

**Step 4**

Apply the load to the specimen at a rate of 50 mm/min (2 in./min).

**Step 5**

Record the maximum compressive strength and continue loading until a vertical crack appears.

**Step 6**

Pull the halves apart and inspect the interior surface for evidence of broken aggregate (Figure 9) and visually estimate moisture damage on a scale of "0" to "5," with 5 being significant moisture damage (as evidenced by stripping of the asphalt from the aggregate).



*Figure 9: Interior surface*

**Step 7**

Record your observations and perform the calculations.

## Calculations

### Step 1

Tensile strength:

*SI Units:*

$$S_t = \frac{2000P}{\pi t D}$$

Where:

$S_t$  = tensile strength, kPa

$P$  = maximum load, N

$t$  = specimen thickness, mm

$D$  = specimen diameter, mm

*US Customary Units:*

$$S_t = \frac{2P}{\pi t D}$$

Where:

$S_t$  = tensile strength, psi

$P$  = maximum load, lbf

$t$  = specimen thickness, in.

$D$  = specimen diameter, in.

### Step 2

Express the numerical index of resistance to the detrimental effect of water as the ratio of the original strength that is retained after the accelerated moisture conditioning. Calculate the tensile strength ratio to two decimal places as follows:

$$\text{Tensile Strength Ratio (TSR)} = \frac{S_2}{S_1}$$

Where:

$S_1$  = average tensile strength of the dry subset, kPa (psi)

$S_2$  = average tensile strength of the conditioned subset, kPa (psi)

### Example Calculations

Determining Tensile Strength

Raw data:

Maximum load, lbf (P): 2.1

Test specimen thickness, in. (t): 2.52 mm

Specimen Diameter, in. (D): 6.04 mm

Tensile strength:

$$S_t = \frac{2000(2.1)}{\pi(2.52)(6.04)} = 87.9 \text{ psi}$$

Determining Tensile Strength Ratio:

Average tensile strength of dry subset, psi ( $S_1$ ): 89.7

Average tensile strength of wet subset, psi ( $S_2$ ): 72.4

$$\text{Tensile Strength Ratio (TSR)} = \frac{72.4}{89.7} = 0.807$$

### Reporting the Test Results

Test reports should include the following information:

- Number of test specimens in each subset.
- Average air voids of each subset.
- Tensile strength of each specimen.
- The calculated TSR.
- Visual observations regarding moisture damage, stripping, and broken aggregate particles.



**Common Errors**

- The vacuum system is set up incorrectly.
- Steps are skipped or performed incorrectly in the specimen conditioning process.
- The temperature of the water bath or freezer is outside of the allowable range.

**Data Sheets**

		WET GROUP			DRY GROUP		
Specimen ID							
Thickness, mm (in.)	t						
Diameter, mm (in.)	D						
Dry mass in air, g		A					
SSD mass, g		B					
Mass in water, g		C					
Volume (B-C), cm <sup>3</sup>		E					
Bulk Specific Gravity (A/E)		$G_{mb}$					
% Air Voids [100 (G <sub>mm</sub> -G <sub>mb</sub> )/G <sub>mm</sub> ]		P <sub>a</sub>					
Volume of air voids (P <sub>a</sub> E/100), cm <sup>3</sup>		V <sub>a</sub>					
Thickness, mm (in.)		t'					
SSD mass, g		B'					
Volume of absorbed water (B'-A), cm <sup>3</sup>		J'					
% saturation (100J'/V <sub>a</sub> )		S'					
Max. Load for Dry, N (lbf)		P					
Dry Strength in: kPa (2000P/πtD) or psi (2P/ πtD)		S <sub>1</sub>					
Average Strength of Dry Group		S <sub>1</sub> avg.					
Max. Load for Wet, N (lbf)		P'					
Wet Strength in: kPa (2000P'/πtD) or psi (2P'/ πtD)		S <sub>2</sub>					
Average Strength of Wet Group		S <sub>2</sub> avg.					
Visual moisture damage (0 to 5 rating)							
Cracked/broken aggregate? (Y/N)							
TSR (S <sub>2</sub> avg. / S <sub>1</sub> avg.)							

## **AASHTO T 312, Preparing and Determining the Density of Hot Mix Asphalt (HMA Specimens by Means of the Superpave Gyrotory Compactor)**

### **Background**

Developed as part of SHRP as an improved laboratory compaction method, the Superpave Gyrotory Compactor (SGC) provides specimens that are much more representative of actual in-service pavements by kneading mixes to simulate construction and traffic loads.

### **Significance and Use**

This standard is used to prepare specimens for determining the mechanical and volumetric properties of hot mix. The specimens simulate the density, aggregate orientation, and structural characteristics obtained during asphalt paving projects.

### **Related Tests and Specifications**

- AASHTO R 35, Superpave Volumetric Design for Hot Mix Asphalt
- AASHTO R 47, Reducing Samples of Hot Mix Asphalt to Testing Size
- AASHTO T 166, Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface Dry Specimens
- AASHTO T 168, Sampling Bituminous Paving Mixtures
- AASHTO T 209, Theoretical Maximum Specific Gravity of Asphalt
- AASHTO T331, Bulk Specific Gravity and Density of Compacted Hot Mix Asphalt Using Automatic Vacuum Sealing Method

### **Timeline for Completion**

Prep Time: 1 hour for plant samples (longer for lab samples)

Prepare a hot mix sample, either by mixing in the lab or sampling from a plant. Bring the material to compaction temperature. Turn on and prepare the gyrotory compactor per the manufacturer's instructions.

Time to Perform Procedure: 5 minutes

Place the sample in to the mold in one lift, load the mold in to the gyrotory compactor, compact the sample, extrude the specimen, and perform density tests.

Calculations: 5 minutes

Calculate both corrected ( $G_{mmx}$ ) and uncorrected relative density ( $\%G_{(mmux)}$ ).

TOTAL TIME: 1 hour (more for lab mixed samples)

## Apparatus

**Superpave Gyratory Compactor** – Capable of applying a pressure of  $600 \pm 18$  kPa to the specimen. Capable of applying an angle of  $20.2 \pm 0.35$  mrad ( $1.16 \pm 0.02$  degrees) to the specimen; capable of operating at a rate of  $30.0 \pm 0.5$  gyrations per minute throughout compaction.

**Specimen Molds** – Inside diameter of 149.90 to 150.00 mm and at least 250 mm in length. See Annex A for mold calibration requirements.

**Ram Head and End Plates** – Flat and smooth; diameter of 149.50 to 149.75 mm.

**Thermometer** – Used for checking temperature of the aggregates, binder, and hot mix.

**Balance** – Meeting the requirements of M 231, Class G 5.

**Oven** – Capable of controlling temperature to  $\pm 3$  °C.

## Sample Preparation

### Laboratory Prepared Specimens

Mix and compact specimens in accordance with Section 8 of T 312.

### Plant Produced Specimens

Obtain specimens in accordance with T 168, reduce in accordance with R 47, and bring the sample to the specified compaction temperature.

## Procedure

### Step 1

Prior to compaction, turn on the gyratory compactor. Allow the machine to warm up, verify the settings, and lubricate bearing surfaces per the manufacturer's instructions.

### Step 2

Remove the preheated mold from the oven. Place a paper disk in the mold.

### Step 3

Place the heated mixture in to the mold in one lift, taking care to avoid segregation. Level the mix, place a paper disk on top of the mix, and load the mold in to the gyratory compactor.

**Step 4**

Apply a pressure of  $600 \pm 18$  kPa to the specimen for the specified number of gyrations (see R 35).

**Step 5**

Remove the mold from the gyratory compactor and extrude the specimen from the mold. Remove the paper disks and allow the specimen to cool.

**Calculations****Step 1**

Calculate the maximum specific gravity of the loose mix in accordance with AASHTO T 209 using a companion sample.

**Step 2**

Determine the bulk specific gravity of the compacted specimen in accordance with AASHTO T 166 or T 331 as appropriate.

**Step 3**

If specimen height is monitored during compaction, record height to the nearest 0.1 mm after each revolution.

**Step 4**

Calculate the uncorrected relative density at any point in the compaction process using the following equation:

$$\%G_{mmux} = \frac{W_m}{V_{mx} G_{mm} G_m} \times 100$$

Where:

$\%G_{mmux}$  = uncorrected relative density at any point during compaction expressed as a percent of the maximum theoretical specific gravity

$W_m$  = mass of the specimen, g

$V_{mx}$  = volume of the specimen, in  $\text{cm}^3$ , at any point based on the diameter ( $d$ ) and height ( $h_x$ ) of the specimen at that point (use mm for height and diameter measurements)

$G_{mm}$  = theoretical maximum specific gravity of the mix

$G_m$  = unity weight of water,  $1 \text{ g/cm}^3$

**Step 5**

Calculate the relative density at any point in the compaction process using the following equation:

$$\frac{G_{mb}h_m}{G_{mm}h_x} \times 100 = \% G_{mnx}$$

Where:

$\% G_{mnx}$  = corrected relative density express as a percent of the maximum theoretical specific gravity

$G_{mb}$  = bulk specific gravity of the extruded specimen

$h_m$  = height in millimeters of the extruded specimen

$h_x$  = height in millimeters of the specimen after x gyrations

**Example Calculations**

Uncorrected relative density:

$$56.77\% = \frac{4800 \text{ g}}{(8,454.04 \text{ cm}^3)(2.534)(1 \frac{\text{g}}{\text{cm}^3})} \times 100$$

Where:

$\%G_{mmux}$  = uncorrected relative density at any point during compaction expressed as a percent of the maximum theoretical specific gravity;

$W_m = 4,800.0 \text{ g}$

$V_{mx} = 8,454.04 \text{ cm}^3$ , based on the diameter (149.75 mm) and height (120.0 mm)

$G_{mm} = 2.534$

$G_m = 1 \text{ g/cm}^3$

Corrected relative density:

$$\frac{2.418 \times 115 \text{ mm}}{2.534 \times 120 \text{ mm}} \times 100 = 91.4\%$$

Where:

$$G_{mb} = 2.418$$

$$G_{mm} = 2.534$$

$$h_m = 115.0 \text{ mm}$$

$h_x = 120.0 \text{ mm}$ , height in millimeters of the specimen after 50 gyrations

### Reporting the Test Results

Report the following information, if applicable:

- Project name
- Date of the test
- Start time of the test
- Specimen identification
- Percent binder in the specimen, nearest 0.1%
- Average diameter of the mold used ( $d$ ), nearest 1.0 mm
- Mass of the specimen ( $W_m$ ), nearest 0.1 g
- Maximum specific gravity ( $G_{mm}$ ) of the specimen by T 209, nearest 0.001
- Bulk specific gravity of the specimen ( $G_{mb}$ ) by T 166, nearest 0.001
- Height of the specimen after each gyration ( $h_x$ ), nearest 0.1 mm
- Relative density ( $\%G_{mm}$ ) express as a percent of the theoretical maximum specific gravity, nearest 0.1%
- Gyration angle, nearest 0.2 mrad (0.01 degrees), and the method used to determine or verify the gyration angle

### Common Errors

The most commonly-observed errors made by technicians performing AASHTO T 312 are as follows:

- Calibration or standardization are performed incorrectly for the 6-in. mold.
- Gyrotory compactor calibration or standardization is not performed (includes angle of gyration, ram pressure, frequency of gyration, LVDT).
- Gyrotory compactor or lubricated properly resulting in angle changes.

## **AASHTO T 331, Bulk Specific Gravity ( $G_{mb}$ ) and Density of Compacted Hot Mix Asphalt (HMA) Using Automatic Vacuum Sealing Method**

### **Background**

Developed as a quick and accurate alternative method for measuring bulk specific gravity of open graded friction course (OGFC).

### **Significance and Use**

This method covers the determination of bulk specific gravity of compacted hot mix asphalt mixtures. This method is to be used in place of T 166 when compacted specimens absorb more than 2.0% of water by volume. This method may also be used as an alternative to T 275.

### **Related Tests and Specifications**

- AASHTO T 166, Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface Dry Specimens
- AASHTO T 275, Bulk Specific Gravity ( $G_{mb}$ ) of Compacted Hot Mix Asphalt (HMA) Using Paraffin-Coated Specimens

### **Timeline for Completion**

Prep Time: 8 hours if wet, less if dry

Dry the specimen to a constant mass. If lab compacted, drying not required.

Time to Perform Procedure: 15 minutes

Record the dry weight in air. Seal the specimen in the appropriate bag and vacuum chamber. Weigh the specimen under water. Check that the specimen was tightly sealed and absorbed no water by reweighing the specimen in air.

Calculations: 10 minutes

Calculate the bulk specific gravity and density.

TOTAL TIME: 1–8 hours

### **Apparatus**

**Balance** – Readable to 0.1% of the sample mass or better, equipped with an underwater weighing apparatus, conforms to M 231.

**Plastic Bags** – Supplied by the manufacturer. Small and large sizes are available, the manufacturer must provide the apparent specific gravity of the bags.

**Vacuum Chamber** – Shall be capable of evacuating the chamber to 5 mm Hg absolute in 60 seconds or less. Equipped with a heat sealing bar to close the specimen bags.



Figure 10: Vacuum chamber

**Sliding Plates** – Level, smooth, and planar. Used to adjust the height of the specimens in the vacuum chamber.

**Suspension Apparatus** – For weighing specimens in water, wire shall be of the smallest practical size.

**Thermometer** – ASTM 17C (17F), having a range of 19 to 27°C (66 to 80°F).

**Water Bath** – For immersing the specimen in water while suspended under the weighing device. Must have an overflow outlet and maintain  $25 \pm 1^\circ\text{C}$  ( $77 \pm 1.8^\circ\text{F}$ ).

**Bag Cutter** – A knife scissors or any other device to quickly open bags.

**Oven** – Capable of maintaining appropriate temperature for drying specimens.



## Sample Preparation

Dry the specimen to a constant mass at a temperature of  $52 \pm 3$  °C ( $125 \pm 5$  °F). Samples saturated with water shall initially be dried overnight and then the mass determined at 2-hour drying intervals. Recently compacted laboratory specimens that have not been exposed to moisture do not require drying. Cool the specimen to room temperature.

## Procedure

### Step 1

Record the initial dry mass as A.

### Step 2

Inspect the bag for any holes and record the mass of the bag. Add this mass to A and designate this mass as B.

### Step 3

Place the specimen in the bag, use sliding plates to position the specimen in the chamber, align the bag opening with the heat sealer, and close the chamber lid. The vacuuming and sealing process will start automatically.

### Step 4

Once the sealing process is completed, open the chamber, and remove the sealed specimen. Ensure that a tight seal has been created and that no holes are present in the bag. Quickly weigh the sealed specimen in a water bath at  $25 \pm 1$  °C ( $77 \pm 1.8$  °F). Fully submerge the specimen, ensuring that no air bubbles are trapped and that the bag is not touching the walls of the bath. Designate this mass as E.

Time matters: The time between the lid opening after sealing and the time to placement of the specimen in the water bath should not exceed 1 minute to reduce the potential for bag leaks.

### Step 5

To ensure a tight seal in the bag, remove the sample from the water, cut the bag open, weigh the specimen, and designate this mass as C.

Moisture check: If the mass A is more than 5 g from the mass of the dry specimen C, the results from this method may not be accurate. The check passes if less than 0.08% is lost or no more than 0.04% is gained. A loss indicates sample material loss and a gain indicates a possible bag leakage problem. Rerun the test using a new bag if this check fails.

## Calculations

### Step 1

Calculate the bulk specific gravity.

$$G_{mb} = \frac{A}{[C + (B - A)] - E - \left[\frac{B - A}{F}\right]} \times 100$$

Where:

$G_{mb}$  = specimen bulk specific gravity

$A$  = initial mass of the dried specimen in air, g

$B$  = calculated mass of the dry, sealed specimen, g

$C$  = final mass of the specimen after removal from the sealed bag, g

$E$  = mass of the sealed specimen underwater, g

$F$  = bag correction factor (apparent specific gravity) of the plastic sealing material at 25°C (77°F), provided by the manufacturer

### Step 2

Calculate the density of the specimen. Round and report to the nearest 1 kg/m<sup>3</sup> (lb./ft<sup>3</sup>).

$$\tilde{n} = G_{mb}(\tilde{a})$$

Where:

$\tilde{n}$  = density of the specimen, kg/m<sup>3</sup> or lb./ft<sup>3</sup>

$G_{mb}$  = bulk specific gravity of the specimen

$\tilde{a}$  = density of water 25 °C (77°F), (997.0 kg/m<sup>3</sup> or 62.2 lb./ft<sup>3</sup>)

## Example Calculations

### Step 1

Calculate the bulk specific gravity.

$$G_{mb} = \frac{A}{[C + (B - A)] - E - \left[\frac{B - A}{F}\right]} \times 100$$

Where:

$G_{mb}$  = specimen bulk specific gravity

$$A = 4,674.6 \text{ g}$$

$$B = 4,723.4 \text{ g}$$

$$C = 4,674.5, \text{ g}$$

$$E = 2,688.5 \text{ g}$$

$$F = 0.812$$

$$2.367 = \frac{4674.6}{[4674.5 + (4723.4 - 4674.6)] - 2688.5 - \left[\frac{4723.4 - 4674.6}{0.812}\right]} \times 100$$

## Step 2

Calculate the density of the specimen. Round and report to the nearest 1 kg/m<sup>3</sup> (lb./ft<sup>3</sup>)

$$\tilde{n} = G_{mb}(\tilde{\alpha})$$

Where:

$\tilde{n}$  = density of the specimen, kg/m<sup>3</sup>

$$G_{mb} = 2.637$$

$$\tilde{\alpha} = 997.0 \text{ kg/m}^3$$

$$2359.9 \text{ kg/m}^3 = 2.637(997.0 \text{ kg/m}^3)$$

## Reporting the Test Results

Round and report the bulk specific gravity to the nearest 0.001. Round and report density to the nearest 1 kg/m<sup>3</sup> (lb./ft<sup>3</sup>).

## Common Errors

- Core-lok device is not standardized correctly or at proper interval.
- The test temperature is outside of the required tolerance.
- Bag correction factor is not available or utilized improperly.

**Data Sheet**

Initial Mass of Sample in Air (A), g	
Mass of Dry, Sealed Specimen (B), g	
Mass After Removal from Sealed Bag (C), g	
Mass of Sealed Specimen in Water (E), g	
Bag Correction Factor (F)	

## **AASHTO T 308, Standard Method of Test for Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Oven**

### **Background Information**

The ignition oven was developed by the National Center for Asphalt Technology (NCAT), and is commonly used for quality control, research and acceptance testing of asphalt mixtures. This test is used as an alternative to the solvent extraction tests and has gained popularity due to the safety concerns of using hazardous solvents.

### **Significance and Use**

This test is used to determine the asphalt binder content of hot mix asphalt by use of an ignition furnace to burn away the asphalt, leaving the aggregate. The remaining aggregate can be used for sieve analysis using AASHTO T 30.

### **Related Tests and Specifications**

- AASHTO M 231, Weighing Devices Used in the Testing of Materials
- AASHTO R 47, Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size
- AASHTO T 2, Sampling of Aggregates
- AASHTO T 30, Mechanical Analysis of Extracted Aggregate
- AASHTO T 40, Sampling Bituminous Materials
- AASHTO T 168, Sampling Bituminous Paving Mixtures
- AASHTO T 248, Reducing Samples of Aggregate to Testing Size
- AASHTO T 329, Moisture Content of Hot Mix Asphalt (HMA) by Oven Method

### **Timeline for Completion**

Preparation Time: 3.5 Hours

Samples must be dried to constant mass, or a moisture content shall be obtained before testing.

Active Testing Time: 3 Hours

Sample is properly placed in the baskets then into the furnace chamber. The time in the chamber is dependent on the amount asphalt and will vary. The sample is then cooled to room temperature and then weighed. Once the sample is weighed, AASHTO T 30 shall be performed.

Calculations: 30 Minutes

The percent of material passing each sieve is calculated and the results are graphed.

TOTAL TEST TIME: 7 Hours

## Apparatus

**Ignition Furnace** – A convection or direct IR irradiation forced-air furnace. A convection type oven must be capable of maintaining the temperature at 578° C (1072°F). The furnace shall be equipment with proper ventilation to expel any smoke and odors away from the laboratory.

For method A, the furnace shall be equipped with an internal balance capable of weighing a 3500 g specimen along with the specimen baskets and accurate to 0.1 g. The furnace shall also display the mass of the specimen and baskets, and have a built-in computer program to calculate the change in mass of the specimen baskets and provide an input of a correction factor for aggregate loss. A printed ticket shall be provided with the initial specimen mass, specimen mass loss, temperature compensation, correction factor, corrected asphalt binder content (percent), test time, and test temperature.

**Specimen Basket and Catch Pan** – Basket shall be constructed of screen mesh, perforated stainless steel plate, or other suitable material and shall completely enclose the specimen. The basket shall be large enough for the specimen to be thinly spread and allow air to flow through and around the specimen particles. The catch pan shall be large enough to retain aggregate particles and melted asphalt that may fall through the specimen baskets. An assembly guard shall be provided to secure the baskets to the pan.

**Oven** – Capable of drying  $110 \pm 5^{\circ}\text{C}$  ( $230 \pm 9^{\circ}\text{F}$ )

**Balance** – Class G2 conforming to the requirements of M 231 and of sufficient capacity.

**Miscellaneous Equipment** – A pan larger than the specimen baskets, spatulas, bowls, and wire brushes.

**Safety Equipment** – Safety glasses or face shield, dust mask, high-temperature gloves, long-sleeved jacket, and protective cage capable of surround the specimen baskets during the cooling period.

**Note: This test method requires the use of extremely high temperatures. Work should be performed on heat-resistant surfaces.**

## Sampling

Obtain samples of freshly produced HMA in accordance with AASHTO T 168. Reduce the specimen in accordance with AASHTO R 47. It may be necessary to warm the sample in an oven at  $110 \pm 5^\circ \text{C}$  ( $230 \pm 9^\circ \text{F}$ ) until it is workable. Do not leave the sample in the oven for an extended period of time.

The size of the specimen shall conform to the mass requirements shown in Table 3. When the specimen mass exceeds the capacity of the equipment, the specimen may be divided into suitable increments and tested and the results combined appropriately for calculation.

*Table 3: Nominal-maximum aggregate size-one size larger than the first sieve to retain more than 10 percent*

Nominal Maximum Size Aggregate mm (mm)	Sieve Size	Minimum Mass Specimen, g
4.75	No. 4	1200
9.5	$\frac{3}{8}$ in.	1200
12.5	$\frac{1}{2}$ in.	1500
19.0	$\frac{3}{4}$ in.	2000
25.0	1 in.	3000
37.5	$1\frac{1}{2}$ in.	4000

**Note: Specimen sizes shall not be more than 500 g greater than the minimum recommended specimen mass.**

### Procedure – Method A

#### Step 1

Convection-type furnace – Preheat the furnace to  $538^\circ \text{C}$  ( $1000^\circ \text{F}$ ) or the temperature determined by the correction factor process.

#### Step 2

Direct IR irradiation-type furnace – use the same burn profile as used during the correction factor determination.

#### Step 3

Oven dry the sample at  $110 \pm 5^\circ \text{C}$  ( $230 \pm 9^\circ \text{F}$ ) to constant mass or determine the moisture content of a companion sample according AASHTO T 329. Enter or manually record the asphalt binder correction factor as determined in the Annex. Determine and record the mass of the specimen basket assembly to the nearest 0.1 g. Prepare the sample as described in the

Sampling Section and place the sample in the catch pans. The specimen shall be evenly distributed using caution to keep the sample away from the edges of the basket. Determine the total mass of the specimen and the specimen assembly. Calculate the initial specimen mass by subtracting the mass of the specimen assembly and enter the specimen mass into the furnace data system.



#### Step 4

Place the specimen basket assembly into the furnace, making sure the assembly is not in contact with the furnace walls. After closing the furnace door, verify the total mass of the specimen and specimen basket assembly is within  $\pm 5$ g. Press start. This operation shall lock the furnace door and start the combustion blower.

#### Step 5

Allow test to continue until the display indicates the test is complete. Remove the specimen and specimen basket assembly and allow to cool to room temperature, under a protective gage, in a safe location. Determine and record the total mass to the nearest 0.1 g and calculate the final mass of the specimen. Use the corrected asphalt binder content (percentage) from the printed ticket. If this value is not correct, subtract the asphalt binder correction. If moisture content was determined per AASHTO T 329, subtract the percent moisture from the asphalt binder content on the printed ticket.

### Procedure – Method B

#### Step 1

Preheat the furnace to 538° C (1000° F) or the temperature determined by the correction factor process.



**Step 2**

Perform Step 3 of Method A

**Step 3**

Place the specimen and specimen basket assembly into the furnace and burn the specimen for at least 45 minutes.

**Step 4**

Remove the specimen and specimen basket assembly and allow to cool to room temperature, under a protective gage, in a safe location. Determine and record the total mass to the nearest 0.1 g.

**Step 5**

Place the specimen and basket back into the furnace and burn the specimen for at least 15 minutes after the furnace reaches the set point temperature. After at least 15 minutes, repeat Step 4.

**Step 6**

Repeat Steps 3-5 until the change in mass does not exceed 0.01 percent of initial specimen mass.

**Step 7**

Calculate and record the final mass of the specimen then calculate the asphalt binder content of the specimen as follows:

$$P_b, \% = \left[ \frac{(M_i - M_f)}{M_i} \times 100 \right] - C_f - MC$$

Where:

$P_b$  = the measured (corrected) asphalt binder content, percent; f

$M_i$  = the total mass of the HMA specimen prior to ignition, g;

$M_f$  = the total mass of aggregate remaining after the ignition, g;

$C_f$  = the correction factor, percent by mass of HMA specimen; and

MC = the moisture content of the companion HMA specimen, percent, as determined by AASHTO T 329. (If the specimen was oven dried prior to initiating the procedure, MC=0.)

**Note: Please refer to the Annex of AASHTO T 308 for more information on the correction factors.**

## Gradation

### Step 1

Allow the contents of the specimen baskets to cool to room temperature. Empty the contents into a flat pan, carefully removing all the material. Use a small wire brush to ensure any residual fines are removed from the baskets and catch pan.

### Step 2

Perform gradation analysis according to AASHTO T 30.



## Reporting Requirements

1. Test method (A or B);
2. Corrected asphalt binder content;
3. Correction factor;
4. Temperature compensation factor (if applicable);
5. Specimen mass;
6. Moisture content (if determined, per T 329; and
7. Test temperature.

### Common Errors

The most commonly-observed errors made by technicians performing AASHTO T 308 are as follows:

- Correction factor was not determined.
- The displayed specimen and specimen basket assembly mass was not verified to be within 5 g of the recorded mass.
- The total sample mass does not meet the minimum requirements.

### Data Sheet

Tare Weight (g):	
Weight Before Burn – Tare (Mi):	
Weight After Burn – Tare: ( <u>Mf</u> ):	
Uncorrected percent Asphalt:	
Corrected percent Asphalt:	

## Appendix A: Lab Materials

### HMEC Module F Asphalt Mixture Tests

Wednesday, March 2, 2016

Please review Page 2 for your grouping and team assignments.

Time	Group A	Group B	Group C	Group D
<i>TBD</i>	<b>Prep Session</b>	<b>Prep Session</b>	<b>Prep Session</b>	<b>Prep Session</b>
<i>TBD</i>	<b>Station 1</b>	<b>Station 2</b>	<b>Station 3</b>	<b>Station 4</b>
<i>TBD</i>	<b>Station 2</b>	<b>Station 3</b>	<b>Station 4</b>	<b>Station 1</b>
<i>TBD</i>	<b>Station 3</b>	<b>Station 4</b>	<b>Station 1</b>	<b>Station 2</b>
<i>TBD</i>	<b>Station 4</b>	<b>Station 1</b>	<b>Station 2</b>	<b>Station 3</b>
<i>TBD</i>	<b>Debrief Session</b>	<b>Debrief Session</b>	<b>Debrief Session</b>	<b>Debrief Session</b>

#### Station 1

- AASHTO R 47 Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size
- AASHTO T 312 Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyrotory Compactor

#### Station 2

- AASHTO T 308 Determining the Asphalt Binder Content of Hot-Mix Asphalt (HMA) by the Ignition Method

#### Station 3

- AASHTO T 283 Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage

#### Station 4

- AASHTO T 166 Bulk Specific Gravity (G<sub>mb</sub>) of Compacted Hot-Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
- AASHTO T 209 Theoretical Maximum Specific Gravity (G<sub>mm</sub>) and Density of Hot-Mix Asphalt (HMA)
- AASHTO T 269 Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
- AASHTO T 331 Compacted Hot Mix Asphalt (HMA) Using Automatic Vacuum Sealing Method

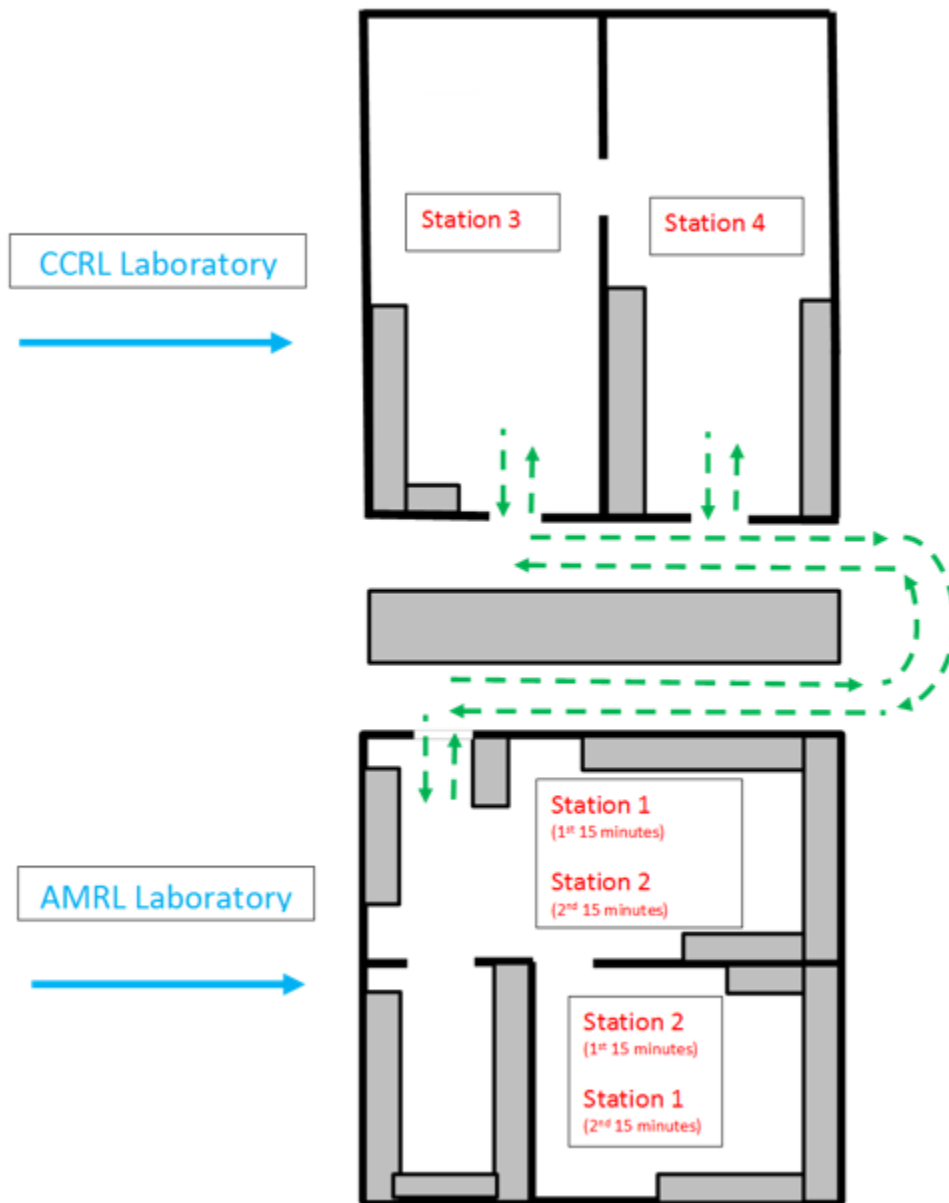
Stations 1 and 2 will be performed in the AMRL Laboratory.

Stations 3 and 4 will be performed in the CCRL Laboratory.

**Team Assignments**

To Be Determined.

AMRL Laboratory Layout for Module F



## 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.

- 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 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 T 312 Superpave Gyratory Compactor

### Checking Gyratory Molds with a Three-Point Bore Gauge

#### *The Benefits of Using a Bore Gauge*

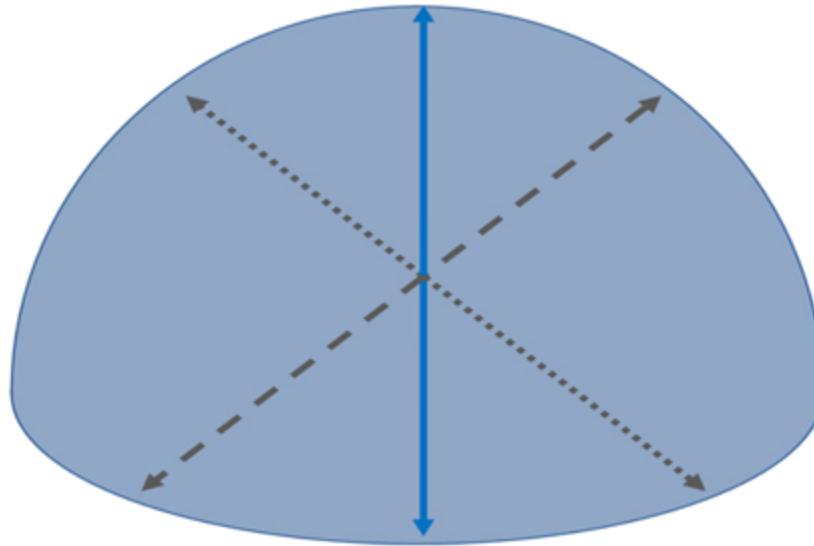
The interior of a gyratory mold, where the compaction actually takes place, is difficult to measure with calipers or by other means. Over time and with increased use, the interior of the mold is prone to wear and distortion. Excessive mold wear can affect achievable densities, and may in turn affect the mix design properties or final product acceptance of asphalt mixtures. T 312 requires that the internal diameter of molds be checked at least annually or after a maximum of 80 hours of use. Regular inspection of gyratory molds can ensure consistency in the compactive effort and volumetric properties of laboratory-compacted asphalt mixtures.

#### *Three Points are Better Than Two... Usually*

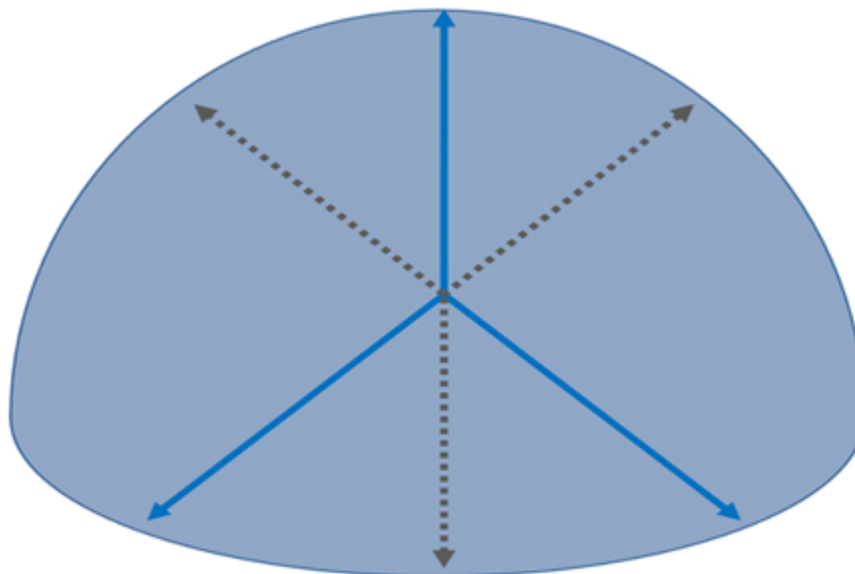
When measuring mold diameters, T 312 limits the type of bore gauge to be used to three-point systems, and does not allow the use of two-point gauges. Two-point bore gauges have several limitations that make them an undesirable tool in measuring gyratory mold diameters. The wear typically seen on gyratory molds is not even, and thus the molds are not perfectly round after repeated use. Over time the molds tend to exhibit lobing effects, or out-of-roundness. If a mold exhibits lobing, it is possible to miss the maximum and minimum diameters when using a two-point measurement system. In the image below, depicting a trilobed deformation, each lobe is located directly across from a flat area. If a two-point bore gauge is used to measure a mold with this shape, each measurement consistently produces the same diameter. Alternatively, if a three-point system is used, the effective diameter of the mold is easily obtained.

Three-point bore gauges have their limitations, too. If a mold deforms into an oval shape, a two-point bore gauge is more likely to detect its true dimensions than a three-point system. However, most molds do not deform in a perfectly trilobed or oval manner. Realistically, molds tend to wear unevenly and form lobes of varying degrees. Industry experts decided that a three-point system would be best-suited for measurement of gyratory molds because it offers the best average result.



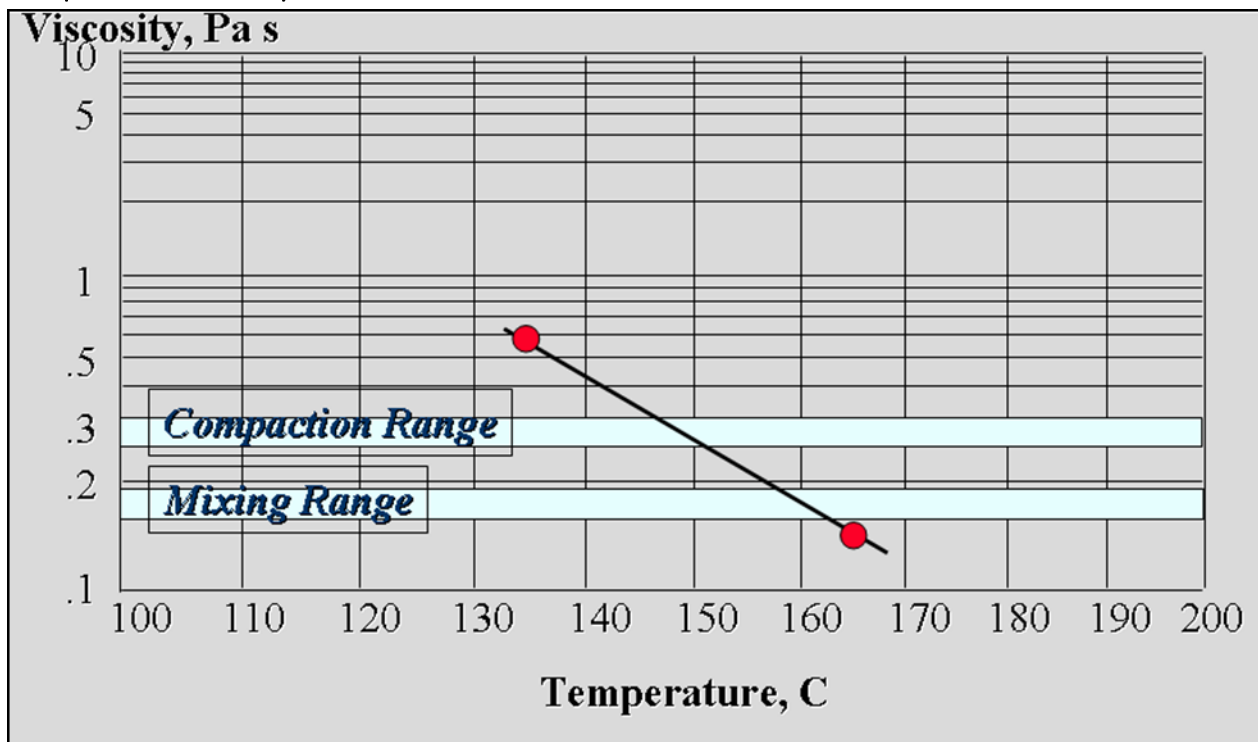


Trilobing is not easily detected when using a two-point bore gauge.



The effective diameter of a trilobed mold is easily detected by use of a three-point bore gauge

## Temperature-Viscosity Charts



The mixing temperature range is defined as the range of temperatures where the unconditioned binder has a viscosity of  $0.17 \pm 0.02$  Pa•s

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

**Station 2: AASHTO T 308 Asphalt Content by Ignition Oven**

SAMPLE 1				SAMPLE 2				EXAMPLE TICKET			
Elapsed Time:	39:00			Elapsed Time:	39:00			Elapsed Time:	39:00		
Sample Weight:	1265 g			Sample Weight:	1268 g			Sample Weight:	1270 g		
Weight Loss:	78.6 g			Weight Loss:	80.5 g			Weight Loss:	79.8 g		
Percent Loss:	6.21%			Percent Loss:	6.35%			Percent Loss:	6.28%		
Temp Comp:	0.17%			Temp Comp:	0.17%			Temp Comp:	0.17%		
Calib. Factor	0.00%			Calib. Factor	0.00%			Calib. Factor	0.26%		
Bitumen Ratio:	6.20%			Bitumen Ratio:	6.34%			Bitumen Ratio:	6.27%		
<b>UN-Calibrated Asphalt Cntnt</b>				<b>UN-Calibrated Asphalt Cntnt</b>				<b>Calibrated Asphalt Cntnt</b>			
6.04%				6.18%				5.85%			
39	495	78.6	6.21*	39	495	80.5	6.35*	39	495	79.8	6.28*
38	495	78.6	6.21	38	496	80.5	6.35	38	494	79.8	6.28
37	497	78.5	6.21	37	498	80.4	6.34	37	495	79.7	6.27
36	499	78.2	6.18	36	499	80.3	6.33	36	495	79.5	6.25
35	502	77.6	6.13	35	501	80.1	6.32	35	497	79.3	6.24
34	507	76.5	6.05	34	502	79.8	6.29	34	499	79.1	6.22
33	509	75.4	5.96	33	504	78.6	6.20	33	503	78.7	6.19
32	510	74.3	5.87	32	505	77.5	6.11	32	506	78.2	6.15
31	512	73.2	5.79	31	507	76.3	6.02	31	509	77.7	6.11
30	513	72.1	5.70	30	508	75.2	5.93	30	513	77.1	6.07
29	515	71.0	5.61	29	510	74.0	5.84	29	516	76.2	6.00
28	516	69.9	5.52	28	511	72.9	5.75	28	519	75.4	5.93
27	518	68.8	5.44	27	513	71.7	5.66	27	521	74.5	5.86
26	519	67.7	5.35	26	514	70.6	5.57	26	524	73.5	5.78
25	520	66.6	5.26	25	515	69.4	5.47	25	526	72.2	5.68
24	522	65.5	5.17	24	517	68.3	5.38	24	528	70.8	5.57
23	523	64.4	5.09	23	518	67.1	5.29	23	529	69.5	5.47
22	525	63.3	5.00	22	520	66.0	5.20	22	530	68.0	5.35
21	526	62.1	4.91	21	521	64.8	5.11	21	531	66.4	5.22
20	528	61.0	4.83	20	523	63.6	5.02	20	531	64.8	5.10
19	529	59.9	4.74	19	524	62.5	4.93	19	532	63.2	4.97
18	531	58.8	4.65	18	526	61.3	4.84	18	536	59.6	4.69
17	532	57.7	4.56	17	527	60.2	4.75	17	536	59.3	4.66
16	534	56.6	4.48	16	529	59.0	4.66	16	536	59.0	4.64
15	535	55.5	4.39	15	530	57.9	4.56	15	537	58.2	4.58
14	539	54.4	4.30	14	539	56.7	4.47	14	539	56.9	4.48
13	540	53.3	4.21	13	550	55.6	4.38	13	546	54.8	4.31
12	569	49.9	3.94	12	570	50.5	3.98	12	563	50.9	4.00
11	604	42.8	3.38	11	618	43.6	3.44	11	612	43.9	3.45
10	639	33.5	2.65	10	645	33.8	2.67	10	640	34.1	2.68
9	541	19.9	1.57	9	536	21.6	1.70	9	536	22.1	1.74
8	450	11.4	0.90	8	461	11.6	0.91	8	459	11.7	0.92
7	444	5.0	0.40	7	452	5.2	0.41	7	439	5.3	0.41
6	437	4.1	0.32	6	444	4.2	0.33	6	433	4.0	0.31
5	431	3.2	0.25	5	435	3.1	0.24	5	427	2.8	0.22
4	424	2.5	0.20	4	426	2.2	0.17	4	420	2.0	0.15
3	418	1.7	0.13	3	418	1.5	0.12	3	414	1.4	0.11
2	411	1.1	0.09	2	409	0.8	0.06	2	409	0.9	0.07
1	409	0.5	0.04	1	410	0.5	0.04	1	411	0.5	0.03
T	TEMP	WT.LOSS	%LOSS	T	TEMP	WT.LOSS	%LOSS	T	TEMP	WT.LOSS	%LOSS
Filter Set Pt:	750°C			Filter Set Pt:	750°C			Filter Set Pt:	750°C		
Chamber Set Point:	500°C			Chamber Set Point:	500°C			Chamber Set Point:	500°C		
Tested By:	_____			Tested By:	_____			Tested By:	_____		
Mix Type:	_____			Mix Type:	_____			Mix Type:	_____		
Sample ID:	_____			Sample ID:	_____			Sample ID:	_____		
Time:	15:30:45			Time:	14:27:16			Time:	15:41:31		
Date:	3-09-97			Date:	3-10-97			Date:	3-11-97		

<b>Binder Correction</b>								
Binder Content Design (%)	UNCORRECTED Binder Content from Oven Ticket Sample 1 (%)	UNCORRECTED Binder Content from Oven Ticket Sample 2 (%)	Difference Between Samples 1 & 2 (%)	Allowable Difference Between Samples 1 & 2 (%)	Sample 1 Correction Factor (=Ticket-Design) (%)	Sample 2 Correction Factor (=Ticket-Design) (%)	Average Correction Factor (%)	Maximum Allowable Correction Factor (%)
5.85				± 0.15				± 1.0

<b>Aggregate Correction</b>							
Sieve Size	Sieve Analysis of "Blank" Specimen (Aggregate Only) Cumulative % Passing	Sample 1 Sieve Results After Burn Cumulative % Passing	Sample 2 Sieve Results After Burn Cumulative % Passing	Difference From The "Blank" Sample 1 (%)	Difference From The "Blank" Sample 2 (%)	Average Difference For Samples 1&2 (%)	Maximum Allowable Difference (%)
12.5-mm (1/2 in.)	100	100	100.0	0	0.0	0.0	± 5.0
9.5-mm (3/8 in.)	95.0	97.2	96.7	-2.2	-1.7	-2.0	± 5.0
4.75-mm (No. 4)	72.0	73.1	72.8	-1.1	-0.8	-0.9	± 5.0
2.36-mm (No. 8)	38.0	39.0	39.2	-1.0	-1.2	-1.1	± 5.0
1.18-mm (No. 16)	21.0	21.5	21.2	-0.5	-0.2	-0.4	± 3.0
600-µm (No. 30)	14.0	14.7	14.5	-0.7	-0.5	-0.6	± 3.0
300-µm (No. 50)	11.0	12.0	11.6	-1.0	-0.6	-0.8	± 3.0
150-µm (No. 100)	8.0	9.2	8.3	-1.2	-0.3	-0.8	± 3.0
75-µm (No. 200)	6.0	6.5	6.3	-0.5	-0.3	-0.4	± 0.5

**Station 2: Other Asphalt Content Determination Methods – AASHTO T 164  
Quantitative Extraction**



*Centrifuge Extraction Method*



*Reflux Extraction Method*



*Vacuum Extraction Method*

## Station 2: Other Asphalt Content Determination Methods – AASHTO T 287 Asphalt Content by Nuclear Method



Advantages and disadvantages of the ignition oven include the following.

Advantages:

- Does not require hazardous chemicals. Some chemicals used in extraction methods are hazardous carcinogens, and these chemicals are costly and difficult to dispose of
- Does not contain a regulated nuclear source
- Test results can be obtained in a few hours. Some chemical extraction methods can take more than a day to complete
- Results in a complete separation of aggregate from the asphalt, which allows the aggregate to be used for further testing.

- Test equipment can operate automatically, allowing technicians to work on other laboratory work.

Disadvantages:

- Potential loss and breakdown of aggregate particles, affecting aggregate gradation. The breakdown may be significant enough to change the aggregate gradation in some cases.
- Asphalt cannot be recovered for further testing.
- Loss of fine aggregate particles can be carried into the ventilation system during ignition, which can cause the calculated asphalt content to be greater than the actual asphalt content.
- High temperatures used during ignition create a heat hazard.
- Requires correction factors to be determined for each mix design, which can be time-consuming. Determining correction factors for mixtures that contain reclaimed asphalt pavement (RAP) or recycled asphalt shingles (RAS) can be difficult.

**Station 3: AASHTO T 283 Tensile Strength Ratio**

Specimen ID		WET GROUP			DRY GROUP		
		1	2	3	4	5	6
Thickness, in.	t	2.4902	2.5098	2.4799	2.4799	2.5201	2.5098
Diameter, in.	D	4.000	4.000	4.000	4.000	4.000	4.000
Max. Load for Dry, lbf	P						
Dry Strength in: psi ( $2P / \pi t D$ )	S <sub>1</sub>						
Average Strength of Dry Group	S <sub>1</sub> avg.						
Max. Load for Wet, lbf	P'						
Wet Strength in: psi ( $2P' / \pi t D$ )	S <sub>2</sub>						
Average Strength of Wet Group	S <sub>2</sub> avg.						
Visual moisture damage (0 to 5 rating)							
Cracked/broken aggregate? (Y/N)							
TSR (S <sub>2</sub> avg. / S <sub>1</sub> avg.)							



**Station 4: AASHTO T 166 Bulk Specific Gravity**

Dry weight (A), g	
SSD weight (B), g	
Immersed weight (C), g	
Bulk specific gravity ( $G_{mb}$ ) $\frac{A}{B-C}$	
Percent water absorbed $\frac{B-A}{B-C} \times 100$	

**Station 4: AASHTO T 209 Theoretical Maximum Specific Gravity****Weighing in Water**

Sample Number	1	2
Dry weight of sample (A), g		
Weight of the vessel in water (B), g	1998.0	1475.4
Weight of the sample in water (C), g		
Max specific gravity, ( $G_{mm}$ ) $\frac{A}{A-(C-B)}$		
Maximum density, (kg/m <sup>3</sup> ) $G_{mm} \times 997.1$		

**Station 4: AASHTO T 269 Air Voids**

Bulk specific gravity (from T 166) ( $G_{mb}$ )	
Maximum specific gravity (from T209) ( $G_{mm}$ )	
Air voids (%) $100 \times [1 - \frac{G_{mb}}{G_{mm}}]$	

**Station 4: AASHTO T 269 Bulk Specific Gravity by Vacuum Sealing Method**

Initial Mass of Sample in Air (A), g	
Mass of Dry, Sealed Specimen (B), g	
Mass After Removal from Sealed Bag (C), g	
Mass of Sealed Specimen in Water (E), g	
Bag Correction Factor (F)	0.998
Bulk Specific Gravity, ( $G_{mb}$ ) $\frac{A}{[C+(B-A)]-E-\frac{(B-A)}{F}}$	