Tex-207-F, Determining Density of Bituminous Compacted Mixtures

Overview

Effective dates: November 2004 – December 2004.

Use this test method to determine the bulk specific gravity of compacted bituminous mixture specimens. Use the bulk specific gravity of the specimens to calculate the degree of densification or percent compaction of the bituminous mixture.

Use Part I for all compacted bituminous mixtures except those with open or interconnecting voids and/or those that absorb more than 2.0 percent water by volume as determined by this procedure.

Use Part II for absorptive mixtures that have more than 2.0 percent water absorption.

Use Part III to determine the in-place density of compacted bituminous mixtures using a nuclear density gauge.

Use Part IV to establish roller patterns for a bituminous pavement.

Use Part V to identify segregation in hot mix asphalt pavement after placement on the roadway.

Use Part VI to determine the bulk specific gravity of compacted bituminous mixtures using the vacuum method.

Use Part VII to perform a longitudinal joint density evaluation of a hot-mix asphalt pavement.

NOTE: Refer to the following table when using Superpave Specifications instead of standard TxDOT specifications. Replace the TxDOT nomenclature with the Superpave nomenclature when required.

Nomenclature Key

TxDOT Nomenclature	**Superpave Nomenclature**
G_a = Bulk specific gravity of the mixture	G_{mb}
G_p = Specific gravity of the paraffin	G_p
G_t = Calculated theoretical maximum specific gravity of the mixture at the specified asphalt content	$G_{max\text{-}theo}$
A_s = Percent by weight of asphalt binder in the mixture	P_b
A_g = Percent by weight of aggregate in the mixture	P_s
G_e = Effective specific gravity of the combined aggregates	G_{se}
G_s = Specific gravity of the asphalt binder determined at 77°F (25°C)	G_b
G_r = Theoretical maximum specific gravity	G_{mm}
G_{rc} = Theoretical maximum specific gravity corrected for water absorption during test	G_{mm}

Units of Measurement

The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

Definitions

The following terms are referenced in this test method:

- Bulk specific gravity - Bulk specific gravity is the ratio of the weight of the compacted bituminous mixture specimen to the bulk volume of the specimen.
- Percent density or percent compaction - The percent density or percent compaction is the ratio of the actual bulk specific gravity of the compacted bituminous mixture specimen to the theoretical maximum specific gravity of the combined aggregate and asphalt contained in the specimen expressed as a percentage.

Section 1

Part I, Bulk Specific Gravity of Compacted Bituminous Mixtures

Use this procedure for all compacted bituminous mixtures except those with open or interconnecting voids and/or those that absorb more than 2.0 percent water by volume.

Apparatus

Use the following apparatus:

- balance, readable to 0.1 g and accurate to 0.5 g, equipped with suitable apparatus to permit weighing the specimen while suspended in water
- mercury thermometer marked in 0.5°C (1°F) divisions or digital thermometer capable of measuring the temperature specified in the test procedure
- water bath for immersing the specimen in water while suspended, equipped with an overflow outlet for maintaining a constant water level
- towel, suitable for surface drying the specimen.

Test Specimens

Test specimens may be laboratory-molded mixtures, pavement cores, or pavement slabs.

Avoid distorting, bending or cracking the specimens during and after removal from pavements or molds. Store specimens in a cool place.

Assure the specimens are free of foreign materials such as seal coat, tack coat, soil, paper, or foil. When any of these materials are visually evident, remove with a saw or by any other satisfactory means.

For roadway cores, the sample size and number of samples must conform to the requirements of "Tex-222-F, Sampling Bituminous Mixtures."

Procedures

- Bulk Specific Gravity of Specimens Containing Moisture

Follow these steps to determine the bulk specific gravity of the compacted bituminous mixture if the specimens contain moisture, such as roadway cores.

Bulk Specific of Gravity Specimens Containing Moisture

Step	Action
1	Determine what type of apparatus to use to weigh the samples suspended in water. Apparatus options: ♦ non-absorptive string ♦ metal bucket or cage attached to the scale with a metal wire or a non-absorptive string.

2	Attach the apparatus to the scale and submerge in water. ♦ Tare the scale with the apparatus submerged in water.
3	♦ Immerse the specimen in a water bath at 25 ± 2°C (77 ± 3°F). Keep specimen in water-bath until the scale readings stabilize.
4	Record specimen weight and designate as ‘C’ under ‘Calculations.’
5	Remove specimen from water. ♦ Dry the surface by blotting quickly with a damp towel and then weigh in air. ♦ Record as the Saturated Surface Dry Weight (SSD), designated as ‘B’ under ‘Calculations.’
6	Oven dry the specimen at a maximum temperature of 60 ± 3°C (140 ± 5°F) or air dry to constant weight. NOTE: Constant weight is defined as the weight at which further drying does not alter the weight by more than 0.05 percent in a two-hour interval.
7	Allow the specimen to cool then weigh in air.
8	Designate this weight as ‘A’ under ‘Calculations.’

♦ Bulk Specific Gravity of Thoroughly Dry Specimens

Follow these steps to determine bulk specific gravity if the specimens are thoroughly dry, such as laboratory molded specimens of HMAC.

Bulk Specific Gravity of Thoroughly Dry Specimens

Step	Action
1	After it has cooled to room temperature, weigh the specimen. ♦ Record and designate this weight as ‘A’ under 'Calculations.'
2	Perform Steps 1-5 in the ‘Bulk Specific Gravity Specimens that Contain Moisture’ procedure.

Calculations

Use the following calculations to determine bulk specific gravity and percent water absorbed by the specimen.

♦ Calculate the Bulk Specific Gravity (G_a) of the specimen:

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

Where:

- A = Weight of dry specimen in air, g
- B = Weight of the SSD specimen in air, g
- C = Weight of the specimen in water, g.

♦ Calculate the percent water absorbed by the specimen (on volume basis):

$$Percent\ absorption = \frac{B - A}{B - C} \times 100$$

If the percent absorption exceeds 2 percent, then use the preferred method 'Part VI, Bulk Specific Gravity of Compacted Bituminous Mixtures Using the Vacuum Method.' If the equipment is not available for this method, then use the alternative 'Part II, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin.'

Section 2

Part II, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin

Use this procedure for absorptive mixtures which have more than 2.0 percent water absorption.

Apparatus

Use the following apparatus:

- balance, readable to 0.1 g and accurate to 0.5 g, equipped with suitable apparatus to permit weighing of the specimen while suspended in water
- water bath, for immersing the specimen in water while suspended, equipped with an overflow outlet for maintaining a constant water level
- mercury thermometer marked in 0.5°C (1°F) divisions or digital thermometer capable of measuring the temperature specified in the test procedure
- sealed glass bulb (or similar object) weighted with lead shot (slightly heavier than an equal volume of water) so that it will submerge when placed in water. The bulb must have a volume of approximately 500 mL (15 oz.).

Test Specimens

Test specimens may be laboratory-molded bituminous mixtures, cores or slabs obtained from bituminous pavements.

Avoid distorting, bending or cracking of the specimen(s) during and after removal from pavements or molds. Store specimens in a safe, cool place.

Assure that specimens are free of foreign materials such as seal coat, tack coat, soil, paper or foil. When any of these materials are visually evident, remove with a saw or by any other satisfactory means.

For roadway cores, the sample size and number of samples must conform to the requirements of "Tex-222-F, Sampling Bituminous Mixtures."

Materials

Use the following materials:

- supply of 120-weight paraffin wax with an approximate melting point of 50°C (120°F)

Procedures

- Determining Specific Gravity for Paraffin

Follow these steps to determine the specific gravity for the paraffin if it is unknown. The manufacturer may provide the specific gravity.

Determining Specific Gravity for Paraffin

Step	Action
1	♦ Weigh the sealed glass bulb in air. ♦ Record and designate this weight as ‘D’ under ‘Calculations.’
2	Determine what type of apparatus to use to weigh the samples suspended in water. Apparatus options: ♦ non-absorptive string ♦ metal bucket or cage attached to the scale with a metal wire or a non-absorptive string
3	♦ Attach the apparatus to the scale and submerge in water. ♦ Tare the scale with the apparatus submerged in water.
4	♦ Submerge the bulb in water at 25 ± 2°C (77 ± 3°F) and weigh to the nearest 0.1 g. ♦ Record and designate this weight as ‘E’ under ‘Calculations.’
5	Heat approximately 2.5 kg (5 lbs.) of paraffin in a 4 L (1 gal.) can until completely melted.
6	After melting the paraffin, allow it to cool until it reaches the temperature at which a very thin film is formed by lightly blowing across the surface. NOTE: This film will form only at the spot where your breath touches the paraffin surface.
7	♦ Dip the sealed glass bulb into the prepared paraffin and withdraw immediately. ♦ Allow the paraffin on the bulb to cool and re-coat the bulb with paraffin two more times.
8	Weigh the paraffin coated bulb, in air, to the nearest 0.1 g. Record and designate the weight as ‘F’ under ‘Calculations.’
9	♦ Submerge the paraffin coated bulb in water at a temperature of 25 ± 2°C (77 ± 3°F) and weigh to the nearest 0.1 g. ♦ Record and designate the weight as ‘G’ under ‘Calculations.’

- Determining Specific Gravity of Compacted Bituminous Mixtures using Paraffin

Follow these steps to determine the Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin.

Bulk Specific Gravity of Compacted Bituminous Mixtures using Paraffin

Step	Action
1	Perform Steps 1 through 9 in the "Determining Specific Gravity for Paraffin" procedure if the specific gravity of the paraffin is not known.
2	♦ Oven-dry the specimen at a maximum temperature of 60 ± 3°C (140 ± 5°F) to constant weight. ♦ Allow the specimen to cool and then weigh the dry specimen in air to the nearest 0.1 g. ♦ Record and designate this weight as ‘A’ under ‘Calculations.’ NOTE: Constant weight is defined as the weight at which further drying does not alter the weight by more than 0.05 percent in a two-hour interval.
3	♦ Prepare the melted paraffin as described in Steps 5 and 6 of the ‘Determining Specific Gravity for Paraffin’ procedure. ♦ Coat the specimen by dipping it into paraffin three times. ♦ Allow the paraffin coating to cool and solidify between each coating.
4	♦ Allow the specimen to cool and weigh the paraffin-coated specimen in air to the nearest 0.1 g.

	♦ Record and designate this weight as 'B' under 'Calculations.'
5	Determine what type of apparatus to use to weigh the samples suspended in water. Apparatus options: ♦ non-absorptive string ♦ metal bucket or cage attached to the scale with a metal wire or a non-absorptive string.
6	♦ Attach the apparatus to the scale and submerge in water. ♦ Tare the scale with the apparatus submerged in water.
7	Completely submerge the suspended paraffin-coated specimen in water at 77 ± 3°F (25 ± 2°C).
8	♦ Weigh the paraffin-coated specimen in water. ♦ Record and designate this weight as 'C' under 'Calculations.' ♦ If it is necessary to remove paraffin coating after determining bulk specific gravity, immerse the specimen for a short time in hot tap water. Remove the cord and peel the paraffin off the specimen. NOTE: An option is to lightly dust the specimen with powdered talc prior to paraffin coating to facilitate paraffin removal.
9	If this method yields a bulk specific gravity that is higher than the bulk specific gravity calculated in "Part I, Bulk Specific Gravity of Compacted Bituminous Mixtures," do not use the results calculated in "Part II, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin." In this case, use the results calculated in "Part I, Bulk Specific Gravity of Compacted Bituminous Mixtures."

Calculations

♦ Calculate the specific gravity of paraffin using the following formula:

$$G_p = \frac{(F - D)}{(F - G - D + E)}$$

Where:

- G_p = Specific gravity of paraffin
- D = Weight (grams) of bulb in air
- E = Weight (grams) of bulb in water
- F = Weight (grams) of paraffin coated bulb in air
- G = Weight (grams) of paraffin coated bulb in water.

♦ Calculate the bulk specific gravity of the compacted specimen:

$$G_a = \frac{A}{B - C - \frac{(B - A)}{G_p}}$$

Where:

- G_a = Bulk specific gravity of specimen
- A = Weight (grams) of specimen in air

- B = Weight (grams) of paraffin-coated specimen in air
- C = Weight (grams) of paraffin-coated specimen in water
- G_p = Specific Gravity of paraffin.

Section 3

Part III, Determining In-Place Density of Compacted Bituminous Mixtures (Nuclear Method)

Use Part III to determine the in-place density of compacted bituminous mixtures using a nuclear density gauge.

Apparatus

Use the following apparatus:

- Nuclear testing gauge capable of making density determinations in thin bituminous pavements
- portable reference standard
- calibration curves for the nuclear gauge
- scraper plate and drill rod guide
- drill rod and driver or hammer
- shovel, sieve, trowel or straightedge and miscellaneous hand tools
- gauge logbook.

Standardization

Follow these steps to standardize the nuclear testing gauge.

Standardizing Nuclear Testing Gauge

Step	Action
1	Turn on the apparatus and allow it to stabilize. NOTE: Follow the manufacturer's recommendations in order to ascertain the most stable and consistent results.
2	Perform standardization with the apparatus located at least 8 m (25 ft.) away from other sources of radioactivity. The area should be clear of large masses or other items which may affect the reference count rate. NOTE: The preferred location for standardization checking is the pavement location being tested. This is the best method for determining day to day variability in the equipment.
3	Using the 'Reference Standard,' take at least four repetitive readings at the normal measurement period and determine the average. NOTE: If available on the apparatus, one measurement period of four or more times the normal period is acceptable. This constitutes one standardization check.
4	♦ The count per measurement period must be the total number of gammas detected during the timed period. ♦ Correct the displayed value for any prescaling built into the instrument. ♦ The prescale value (F) is a divisor which reduces the actual value for the purpose of display. ♦ The manufacturer will supply this value if other than 1.0. ♦ Record this corrected value as N_s.

5	Use the value of N_s to determine the count ratios for the current day's use of the instrument. If for any reason the measured density becomes suspect during the day's use, perform another standardization check.

The following table shows the required actions to take based on the results from Step 3 of the 'Standardizing Nuclear Testing Gauge' procedure.

Reference Standard	
If . . .	**Then. . .**
the value obtained is within the limits stated in limits calculation	the apparatus is considered to be in satisfactory operating condition and the value may be used to determine the count ratios for the day of use.
the value is outside these limits	allow additional time for the apparatus to stabilize, make sure the area is clear of sources of interference, then conduct another standardization check.
the second standardization check is within the limits	the apparatus may be used.
the second standardization check also fails the test	the apparatus must be adjusted or repaired as recommended by the manufacturer.

Calculations

Use these calculations in Step 3 of the 'Standardizing Nuclear Testing Gauge' procedure:

The limits are:

$$(N_s - N_o) \leq 2.0\sqrt{N_o / F}$$

Where:

- N_s = value of current standardization count
- N_o = average of the past four values of N_s taken previously
- F = value of any prescale.

Procedure

Follow these steps to determine the in-place density of compacted bituminous mixtures using a nuclear density gauge.

Determining In-Place Density of Compacted Bituminous Mixtures (Nuclear Method)	
Step	**Action**
1	♦ Select a test area that is relatively free of loose material, voids or depressions. ♦ The area must be at least 300 mm (12 in.) away from surface obstructions such as curbing, etc. ♦ Fill minor depressions with fine sand or native fines. ♦ Avoid elevating the gauge above the surface of the material to be tested.
2	Make density determinations in either the backscatter or direct transmission modes; however,

	to use the direct transmission method, the lift must be at least 51 mm (2 in.) thick.
3	Perform Steps 3 – 5 when determining the in-place density of compacted bituminous mixtures using a nuclear density gauge in the backscatter mode.
4	Place the gauge on the test area making sure that the base is firmly seated and in full contact with the surface.
5	With the probe in the backscatter position, record the readings that are required at each location for the particular gauge being used. ♦ Where the surface is still hot, avoid leaving the gauge in one position too long as erratic readings may result. ♦ Proceed to Step 11.
6	Perform Steps 6 – 10 when determining the in-place density of compacted bituminous mixtures using a nuclear density gauge in the direct transmission mode.
7	Using the drive pin and guide plate, make a hole 51 mm (2 in.) deeper than the transmission depth being used. ♦ The hole must be as close as possible to 90 degrees from the plane surface.
8	Place the gauge on the prepared surface so that the base is firmly seated and in full contact with the surface.
9	Adjust the probe to the desired transmission depth and pull the gauge so that the probe is in contact with the side of the hole nearest the detector tubes.
10	♦ Measure and record the readings that are required for each location for the particular type of gauge being used. ♦ Proceed to Step 11.
11	Use one of the following methods to determine the in-place density. ♦ Determine the nuclear density by dividing the field counts by the standard counts. ♦ Use the appropriate calibration curves if necessary. ♦ Most models are now programmable to allow direct reading of the nuclear density or percent compaction.
12	When correlating the nuclear density to the actual density of the compacted material, take cores or sections of the pavement from the same test area selected for the nuclear tests.
13	Determine the actual specific gravity (G_a) of the test cores or samples according to 'Part I, Part II,' or 'Part III.' ♦ Use at least seven core densities and seven nuclear densities to establish a conversion factor. ♦ Once the conversion factor is determined, adjust the nuclear density readings using this factor to correlate with the actual G_a determined through laboratory testing. When testing thin lifts in the back scatter mode, the influence of underlying strata with varying densities may render this procedure impractical without special planning. Most manuals for the nuclear gauge describe the various methods to use with thin lifts.
14	♦ When controlling in-place density with the nuclear gauge, make correlations as described in Step 12 and compare the correlated nuclear density to the G_r or G_{rc} of the mixture. ♦ Calculate the percent density or directly read programmable models to readily determine air-void content.

Section 4

Part IV, Establishing Roller Patterns (Control Strip Method)

Use this procedure to establish roller patterns for bituminous pavement.

Apparatus

Use the following apparatus:

- nuclear testing gauge capable of making density determinations in thin bituminous pavements
- electrical impedance (non-nuclear) measurement gauge (optional)
- portable reference standard
- calibration curves for the nuclear gauge
- scraper plate and drill rod guide
- drill rod and driver or hammer
- shovel, sieve, trowel or straightedge and miscellaneous hand tools
- gauge logbook.

Procedure

Follow these steps to establish roller patterns using the control strip method.

Establishing Roller Patterns (Control Strip Method)

Step	Action
1	Refer to gauge manufacturer's recommendations for operating the gauge. NOTE: Standardize the equipment at the start of each day's use as described in "Part III, Determining In-Place Density of Compacted Bituminous Mixtures (Nuclear Method)" of this test method when using a nuclear density gauge.
2	Establish a control strip approximately 90 m (300 ft.) long and at least 3.5 m (12 ft.) wide or the width of the paving machine being used. ♦ Select three test sites. ♦ Avoid areas near edges or overlap of successive passes of the rollers.
3	Allow the roller to complete at least two coverages of the entire control strip prior to checking the density. ♦ Perform density tests at the three test sites selected. ♦ Record results. ♦ Mark each test site very carefully so that subsequent tests can be made in exactly the same position and location. ♦ Use a colored marker keel to outline the gauge before taking the readings. ♦ To prevent cooling of unrolled areas, take the tests as quickly as possible and release rollers to complete additional coverage.
4	Repeat the density tests at the previously marked test sites. ♦ Continue this process of rolling and testing until there is no significant increase in density.

	♦ Try several different combinations of equipment, and numbers of passes with each combination, to determine the most effective rolling pattern. ♦ It is not desirable in some cases for a peak density to be achieved with a piece of equipment prior to beginning a pass with the next roller. ♦ Final, in-place density is the measure of rolling pattern effectiveness.
5	After completion of the control strip tests, construct another section, without interruption, using the roller patterns and number of coverages determined to be required by the control strip. ♦ Take random density tests on this section to verify the results from the control strip. ♦ Since this section may be completed in a shorter length of time than the control strip, it may be possible to reduce the required coverages based on these tests.
6	Make density tests for job control according to the Guide Schedule for Sampling and Testing or, as often as necessary, when indicated by some changes in the material being compacted.

Notes

Visual observation of the surface being compacted is a very important part of this procedure. If obvious signs of distress are observed while rolling, such as cracking, shoving, etc., cease rolling and get an evaluation of the roller pattern. Structural failures, due to over compaction, will cause the density tests to indicate the need for more compaction. Take particular care and observe closely when using vibratory rollers since they are more likely to produce over-compaction in the material.

When taking density tests on hot material with the use of the nuclear density gauge, take the minimum test time allowed by the particular gauge being used since the gauge may display erratic results if it is overheated.

Some specifications require compaction of the material while temperatures are above 80°C (175°F).

Exercise particular care to clean the bottom of the gauge after it is used on asphalt pavement.

When using specified density and rolling patterns, the correlation procedures outlined in "Part III," Step 13 can be used.

This procedure is intended to be a general guide. Follow the instruction manual furnished with the particular density gauge for specific operation of that gauge. This is essential since several different models and different brands are in standard use by TxDOT.

Nuclear gauges and the user of the nuclear gauges must meet all requirements of the TxDOT's Radioactive Material License, "Nuclear Gauge Operating Procedures," and the *Texas Rules for Control of Radiation.*

Section 5

Part V, Determining Mat Segregation Using a Density Testing Gauge

Use this procedure to identify segregation in bituminous pavement after placement on the roadway.

Apparatus

Use the following apparatus:

- ♦ nuclear density gauge
- ♦ thin lift density gauge (optional)
- ♦ electrical impedance (non-nuclear) measurement gauge (optional)
- ♦ measuring tape (optional)
- ♦ forms.

Procedure

Follow these steps to determine the mat segregation using a nuclear density gauge.

Determining Mat Segregation Using a Density Testing Gauge

Step	Action
1	Refer to gauge manufacturer's recommendations for operating the gauge. NOTE: It is not necessary to calibrate the gauge to the mix.
2	A profile section is defined as a 15.2 m (50 ft.) length of mat with readings taken approximately every five feet. Additional longitudinal readings may be taken along the transverse offset where visible segregation is noticed.
3	Perform this step when profiling location where it is known that the paver stopped. ♦ Identify the location where the lay-down machine stopped paving for some reason, such as sporadic mix delivery. ♦ Mark and record this location as the beginning of the profiled section, also called the zero point. ♦ The first reading location should be approximately ten feet behind the zero point. ♦ Proceed to Step 5.
4	Perform this step when profiling a location where it is not known if the paver stopped. ♦ Randomly select an area. ♦ If possible, choose an area with visible segregation. ♦ Proceed to Step 5.
5	♦ Determine the transverse offset two feet or more from the pavement edge. ♦ Do not vary from this line. ♦ Visually observe the mat and note surface texture in the section to be profiled. ♦ Make note of areas that appear to be segregated. ♦ Visually segregated areas, if any, must be included in the section to be profiled. ♦ Profile segregated areas with longitudinal streaking greater than the profile length as directed in Step 6.

<table>
<tr><td>6</td><td>Perform this step when profiling an area with segregation of longitudinal streaking greater than the profile length.
♦ Profile the area at an angle in a diagonal direction.
♦ Start profile with a transverse offset of 0.6 m (2 ft.) from the center of the longitudinal streak.
♦ End profile with a transverse offset of 0.6 m (2 ft.) on the opposite side of the longitudinal streak.
♦ Do not start or end a profile less than one foot from the pavement edge.</td></tr>
<tr><td>7</td><td>After completion of the final rolling patterns, position the gauge at the identified location.
♦ Use of a nuclear density gauge
• Take 3 one-minute readings (minimum time length, longer readings can be used) in backscatter mode when using a nuclear density gauge at each random sample location.
• It is optional to use fine sand passing the 0.425 mm (No.40) sieve size to fill any voids without elevating the gauge above the rest of the mat.
♦ Use of an electrical impedance gauge
• Take 2 readings beginning with a reading at the center and moving clockwise around the center moving the instrument at least 50 mm (2 in.) between readings when using an electrical impedance gauge at each random sample location.
♦ Record the in-place density gauge readings.</td></tr>
<tr><td>8</td><td>Before moving the gauge, average the readings.
♦ Compare each individual reading to the average.
♦ Discard any single readings that vary more than 16 kg/m^3 (1 lb/cf) from the average.
♦ Take additional readings to replace any that are discarded until three readings have been obtained that are within 16 kg/m^3 (1 lb/cf) of the average.</td></tr>
<tr><td>9</td><td>Move the gauge approximately 1.5 m (5 ft.) forward in the direction of the paving operation.
♦ If a segregated area is visible in between the 1.5 m (5 ft.) distance, take an additional set of readings at that location.</td></tr>
<tr><td>10</td><td>♦ Repeat Steps 7, 8 and 9.
♦ Continue to take readings until a minimum of ten sets of three readings has been completed.
♦ Impedance gauge readings may be verified with the use of the nuclear gauge.</td></tr>
<tr><td>11</td><td>Determine the average density from all locations.</td></tr>
<tr><td>12</td><td>Determine the difference between the highest and lowest average density.</td></tr>
<tr><td>13</td><td>Determine the difference between the average and lowest average density.</td></tr>
<tr><td>14</td><td>Record the data using the example of ‘Segregation Profile Form.’</td></tr>
</table>

Section 6

Part VI, Bulk Specific Gravity of Compacted Bituminous Mixtures Using the Vacuum Method

Use this procedure to determine the bulk specific gravity of compacted bituminous mixtures using the Vacuum Device. This procedure is applicable for Permeable Friction Course (PFC), gap graded mixtures such as Coarse Matrix High Binder (CMHB), Stone Matrix Asphalt (SMA), Superpave and any other mixtures that have more than 2.0 percent water absorption by volume.

Apparatus

Use the following apparatus:

- specialized vacuum sealing device
- balance, readable to 0.1 g and accurate to 0.5 g, equipped with suitable apparatus to permit weighing of the specimen while suspended in water
- water bath, for immersing the specimen in water while suspended from a scale, equipped with an overflow outlet for maintaining a constant water level.

Test Specimens

Test specimens may be laboratory-molded mixtures, pavement cores, or pavement slabs.

Avoid distorting, bending or cracking the specimens during and after removal from pavements or molds. Store specimens in a cool place.

Assure the specimens are free of foreign materials such as seal coat, tack coat, soil, paper, or foil. When any of these materials are visually evident, remove with a saw or by any other satisfactory means.

For roadway cores, the sample size and number of samples must conform to the requirements of "Tex-222-F, Sampling Bituminous Mixtures."

Materials

Use the following materials:

- Supply of large (approximately 16 in. x 16 in.) and small (approximately 14 in. x 10 in.) specialized polymer bags with the apparent specific gravity provided by the manufacturer.

Procedures

- Vacuum Device Setup

Follow these steps to perform the vacuum device setup.

Vacuum Device Setup	
Step	**Action**
1	Set the vacuum timer. NOTE: The vacuum pump timer setting and exhaust is calibrated and set at the factory to eliminate drift and measurement variability due to the sealing process. The vacuum pump operates for approximately one minute. If the vacuum pump stops before this time has elapsed, contact the manufacturer for adjustments.
2	Set the sealing bar timer in accordance with the vacuum device manufacturer's recommendations. NOTE: Inspect the seal quality after the first sealing operation. If the polymer bag stretches or burns, reduce the setting. If the seal is not complete or the bag is easily separated, increase the setting.

- Bulk Specific Gravity of Compacted Bituminous Mixtures using a Vacuum Device

Follow these steps to perform the bulk specific gravity of compacted bituminous mixtures using a vacuum device.

Bulk Specific Gravity of Compacted Bituminous Mixtures Using a Vacuum Device	
Step	**Action**
1	If using roadway cores or cores that contain moisture, perform the following steps. ♦ Oven dry specimens that contain moisture at a maximum temperature of 60 ± 3°C (140 ± 5°F) to a constant weight. NOTE: Constant weight is defined as the weight at which further drying does not alter the weight by more than 0.05 percent in a two-hour interval.
2	♦ Allow the specimen to cool to room temperature, then weigh in air to the nearest 0.1 g. ♦ Record and designate this weight as 'A' under 'Calculations.' ♦ Proceed to Step 4.
3	If using laboratory molded specimens or dry specimens, perform the following steps. ♦ Allow laboratory-molded specimens or thoroughly dry specimens to cool to room temperature and then weigh the specimen in air to the nearest 0.1 g. ♦ Record and designate this weight as 'A' under 'Calculations.' ♦ Proceed to Step 4.
4	Open the lid of the vacuum device. Stack or remove rectangular spacer plates in the vacuum chamber of the vacuum device such that there is adequate space for the test specimen.
5	Place a sliding plate in the vacuum chamber on top of the spacer plate(s) away from the seal bar. The sliding plate is placed in the chamber to reduce friction during the sealing operation.
6	Select the large or small polymer bag to use. ♦ Use a large polymer bag for specimens with a diameter of 152.4 mm (6 in.) and a height or thickness greater than 50.8 mm (2 in.), i.e., Superpave gyratory molded specimens or field cores greater than 50.8 mm (2 in.) in thickness. ♦ Use a small polymer bag for specimens with a diameter of 101.6 mm and 152.4 mm (4 and 6 in.) and a height or thickness less than 50.8 mm (2 in.).
7	Weigh the selected polymer bag and record and designate the weight as 'B' under 'Calculations.'
8	Determine the polymer bag 'Correction Factor' (CF). ♦ Calculate the ratio, 'R,' by dividing the weight of the specimen by the weight of the bag. ♦ Use the Correction Factor Table provided by the manufacturer in the Operator's Guide.

	♦ Look up the calculated 'R' value and record and designate the corresponding correction factor from the table as 'CF.'
9	Perform Steps 9-16 to vacuum seal the specimens and to calculate G_a. ♦ Place the bag inside the chamber. ♦ Place the specimen in the polymer bag carefully avoiding punctures and tearing. ♦ Center the core in the bag leaving approximately 25.4 mm (1 in.) of slack on the backside. Specimens with a diameter of 152.4 mm (6 in.) and a height or thickness greater than 2 in. (50.8 mm) shall be placed in the device with the circular 152.4 mm (6 in.) diameter face pointing upwards.
10	Position the bag such that approximately 25.4 mm (1 in.) of the open end of the bag is evenly placed against the sealing bar.
11	Close the lid of the vacuum device and hold firmly for 2 to 3 seconds. ♦ The vacuum pump will start and the lid will stay closed on its own. ♦ The vacuum gauge will read a vacuum of less than 50 mm-Hg (28 in-Hg).
12	♦ The lid of the vacuum device will automatically open upon completion of the sealing process. ♦ Carefully remove the sealed specimen from the chamber. ♦ Gently pull on the polymer bag to ensure that the seal is tightly conformed to the specimen. ♦ A loose seal is an indication of a leak. If there is a leak, repeat Steps 7-9.
13	Determine what type of apparatus to use to weigh the samples suspended in water.
14	♦ Attach the apparatus to the scale and submerge in water. ♦ Tare the scale with the apparatus submerged in water.
15	♦ Completely submerge the sealed specimen in water at 77 ± 3°F (25 ± 2°C) and record the weight of the specimen in the bag. ♦ Make sure that the polymer bag does not touch the sides of the water bath. ♦ Weigh the sealed specimen in water. ♦ Record the weight to the nearest 0.1 g when the scale reading stabilizes. ♦ Designate this weight as 'C' under 'Calculations.'
16	♦ Remove the specimen from the polymer bag and reweigh the specimen in air. ♦ Compare this weight to the weight recorded for 'A' during Step 2 or 3. ♦ If the difference in weight is more than 5 grams, a leak may have occurred. ♦ Dry the sample to a constant weight at 60°C (140°F) and redo the procedure with a new polymer bag. NOTE: Constant weight is defined as the weight at which further drying at 60 ± 3°C (140 ± 5°F) does not alter the weight by more than 0.05 percent in a two-hour interval.

Calculations

♦ Calculate the bulk specific gravity of the compacted specimen using the following formula:

$$G_a = \frac{A}{\left((A+B)-C\right)-\frac{B}{CF}}$$

Where:

- G_a = bulk specific gravity
- A = weight of specimen in air
- B = weight (grams) of the polymer bag in air
- C = weight (grams) of sealed specimen in water
- CF = Correction Factor

Section 7

Part VII, Determining Longitudinal Joint Density Using a Density Testing Gauge

Use this procedure to perform a longitudinal joint density evaluation on hot-mix asphalt pavement.

Apparatus

Use the following apparatus:

- nuclear density gauge
- thin lift density gauge (optional)
- electrical impedance (non-nuclear) measurement gauge (optional)
- measuring tape (optional)
- forms.

Procedures

- Performing a Longitudinal Joint Density Using a Density Testing Gauge

Follow these steps to perform a longitudinal joint density evaluation on hot-mix asphalt pavement.

Performing a Longitudinal Joint Density Using a Density Testing Gauge	
Step	**Action**
1	Refer to gauge manufacturer's recommendations for operating the gauge.
2	♦ Identify the random sample location selected for in-place air void testing. ♦ Mark and record this location as the reference point where the joint evaluation is to be performed. • This point must be more than 0.6 m (2 ft.) from the pavement edge.
3	After completion of the final rolling pattern, position the gauge at the random sample location selected for in-place air void testing.
4	♦ Use of a nuclear density gauge: • Take 3 one-minute readings (minimum time length, longer readings can be used) in backscatter mode when using a nuclear density gauge. • It is optional to use fine sand passing the 0.425 mm (No.40) sieve size to fill any voids without elevating the gauge above the rest of the mat. ♦ Use of an electrical impedance gauge: • Take 2 readings beginning with a reading at the center and moving clockwise around the center moving the instrument at least 50 mm (2 in.) between readings when using an electrical impedance gauge.
5	Record the density measurements from the density gauge at each random sample location selected for in-place air void testing.
6	Perform a longitudinal joint density evaluation at the right and left edge of the mat which is or will become a longitudinal joint. The location should be perpendicular to the random sample

	location selected for in-place air void testing. ♦ Identify the joint type as 'Confined' or 'Unconfined.' ♦ Additional readings may be taken along the longitudinal joint where visible irregularities or segregation is noticed.
7	Position the gauge with the center of the gauge placed at 20.3 cm (8 in.) from the pavement edge that is or will become a longitudinal joint. Orient the gauge such that the longer dimension of the gauge is parallel to the longitudinal joint.
8	♦ Use of a nuclear density gauge: • Take 3 one-minute readings (minimum time length, longer readings can be used) in backscatter mode when using a nuclear density gauge. • It is optional to use fine sand passing the 0.425 mm (No.40) sieve size to fill any voids without elevating the gauge above the rest of the mat. ♦ Use of an electrical impedance gauge: • Take 2 readings beginning with a reading at the center and moving clockwise around the center moving the instrument at least (2 in.) between readings when using an electrical impedance gauge.
9	Record the joint density from the location evaluated.
10	Determine the difference in density between the readings taken at the random sample location selected for in-place air void testing and the readings taken along the longitudinal joint. *NOTE:* Impedance gauge readings may be verified with the nuclear density gauge.
11	Record and report the data using the example of the 'Longitudinal Joint Density Worksheet.'

- Correlating the Joint Density

Follow these steps to determine a correlated joint density.

Correlating the Joint Density	
Step	**Action**
1	Measure the bulk specific gravity of the cores taken from each random sample location selected for in-place air void testing according to "Tex-207-F, Determining Density of Compacted Bituminous Mixtures."
2	Record the average Rice Specific Gravity for the lot being evaluated for joint density.
3	Convert the bulk and average Rice Specific Gravity to pounds per cubic foot by multiplying by the density of water 998 kg/m^3 (62.4 lb/cf).
4	Determine the density gauge correlation factor. ♦ Record the average density gauge reading at the interior mat random sample location for in-place air voids. ♦ Record the average bulk specific gravity in kg/m^3 (lbs/cf) of the cores taken at the random sample location for in-place air voids. ♦ Subtract the average density gauge reading (a) from the average bulk specific gravity in kg/m^3 (lbs/cf) of the cores (b).
5	Add this value to the density gauge readings at each location evaluated for joint density.
6	Record and report the data using the example of the "Longitudinal Joint Density Worksheet."

Report Format

The following Excel programs may be used to calculate and report density findings.

- QC/QA (used in conjunction with Hot Mix specification) test data worksheets (Tx2QCQA). (Refer to the 'Help' tab for detailed instructions on how to use the program.)
- 'Segregation Density Profile Form'
- 'Longitudinal Joint Density Profile Form.'

Other Related Calculations

- Calculate the theoretical maximum specific gravity of the specimen for mixture design density calculations:

$$G_t = \frac{100}{\frac{A_g}{G_e} + \frac{A_s}{G_s}}$$

Where:

- G_t = Calculated theoretical maximum specific gravity of the mixture at the asphalt content A_s. The G_t is required during the mix design phase to calculate the percent density or compaction for each asphalt content. This value is also used to verify the results of the Rice Gravity laboratory test and ensure that the correct percentages of asphalt and aggregates are in the mixture.
- A_g = Percent by weight of aggregate in the mixture
- A_s = Percent by weight of asphalt binder in the mixture
- G_e = Effective specific gravity of the combined aggregate (see "Tex-204-F, Design of Bituminous Mixtures, [Part I, Typical Example of Design by Weight]") for the formula)
- G_s = Specific gravity of the asphalt binder determined at 25°C (77°F).

NOTE: Use G_e when it is desired to correct for asphalt absorption into the aggregates.

- Calculate the percent density or percent compaction of the specimen:

$$Percent\ Density = \frac{G_a}{G_t\ or\ G_r\ or\ G_{rc}} \times 100$$

Where:

- G_a = Actual bulk specific gravity of specimen
- G_t = Theoretical maximum specific gravity of specimen
- G_r = Theoretical maximum specific gravity ("Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures")
- G_{rc} = Theoretical maximum specific gravity, corrected ("Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures").

♦ Calculate the percent air voids in a compacted specimen:

$$Percent\ \ Air\ Voids = \left[1 - \frac{G_a}{G_r\ \ or\ G_{rc}} \right] \times 100$$

Where:

- G_a = Actual bulk specific gravity of specimen
- G_r = Theoretical maximum specific gravity ("Tex-227, Theoretical Maximum Specific Gravity of Bituminous Mixtures")
- G_{rc} = Theoretical maximum specific gravity, corrected ("Tex-227, Theoretical Maximum Specific Gravity of Bituminous Mixtures").

In designing mixtures under cold-mix asphaltic concrete specifications, the theoretical specific gravity (G_t) must be calculated on the residual asphalt content of the cured mixture. In this case, G which is the Average Bulk Specific Gravity of the combined aggregate (see "Tex-201-F, Bulk Specific Gravity and Water Absorption of Aggregate") may be used in lieu of G_e.

For example, assume a mixture containing 6% RC-2 cutback asphalt and 94% aggregate. Assume the test report for the RC-2 shows residual asphalt content to be 78.2% by weight.

- G = 2.652 Average bulk specific gravity of aggregate
- G_s = 1.010 Specific gravity of asphalt at 25°C (77°F) of residual bitumen from RC-2.

Then:

The 6% RC-2 will have 6.0 x .782 = 4.7% residual asphalt.

The total mixture of aggregate and residual asphalt will be equal to 94.0 + 4.7 or 98.7%.

Calculated on basis of 100 percent cured mixture:

$$A_g = \frac{94.0}{98.7} X 100 = 95.2$$

$$A_s = \frac{4.7}{98.7} X 100 = 4.8$$

$$95.2 + 4.8 = 100\%$$

The theoretical specific gravity of the cured mixture is equal to 2.460.

$$G_t = \frac{100}{\frac{95.2}{2.652} + \frac{4.8}{1.010}} = 2.460$$

♦ Calculate the voids in the mineral aggregate (VMA) of compacted specimens:

$$VMA = 100 - \frac{G_a}{G_r \ or \ G_{rc}} \ X \ (100) + \frac{G_a \ X \ \%\text{AC}}{G_s}$$

Where:

- G_a = Average actual bulk specific gravity of three specimens compacted according to "Tex-206-F, Compacting Specimens Using the Texas Gyratory Compactor (TGC)"
- G_r = Theoretical maximum specific gravity according to "Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures"
- G_{rc} = Theoretical maximum specific gravity of specimen, corrected ("Tex-227-F Theoretical Maximum Specific Gravity of Bituminous Mixtures")
- % AC = Asphalt content
- G_s = Specific gravity of asphalt.

Section 8

Archived Versions

Archived versions of "Tex-207-F, Determining Density of Compacted Bituminous Mixtures" are available through the following links:

- Click on 207-0899 for the test procedure effective August 1999 through October 2004.