

Test Procedure for

DETERMINING DENSITY OF COMPACTED BITUMINOUS MIXTURES



TxDOT Designation: Tex-207-F

Effective Dates: May 2007–August 2007.

1. SCOPE

- 1.1 This test method determines the bulk specific gravity (G_a) of compacted bituminous mixture specimens. Use the G_a of the specimens to calculate the degree of densification or percent compaction of the bituminous mixture.
- 1.2 Refer to the following table when using Superpave specifications instead of standard department specifications. Replace Department nomenclature with the Superpave nomenclature when required.

Table 1—Nomenclatures and Definitions

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

- 1.3 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.

2. DEFINITIONS

- 2.1 *Bulk Specific Gravity*— G_a is the ratio of the weight of the compacted bituminous mixture specimen to the bulk volume of the specimen.
- 2.2 *Percent Density or Percent Compaction*—The percent density or percent compaction is the ratio of the actual G_a 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.

PART I—BULK SPECIFIC GRAVITY OF COMPACTED BITUMINOUS MIXTURES

3. SCOPE

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

4. APPARATUS

- 4.1 *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
- 4.2 *Suspension Apparatus, Nonabsorptive String, Metal Bucket, or a Cage*—attached to the balance with a metal wire or a nonabsorptive string
- 4.3 *Mercury Thermometer*—marked in 1°F (0.5°C) divisions or digital thermometer capable of measuring the temperature specified in the test procedure
- 4.4 *Water Bath*—for immersing the specimen in water while suspended, equipped with an overflow outlet for maintaining a constant water level
- 4.5 *Towel*—suitable for surface drying the specimen
- 4.6 *Vacuum Device*—such as Corelok or Coredryer (optional).

5. TEST SPECIMENS

- 5.1 Test specimens may be laboratory-molded mixtures, pavement cores, or pavement slabs.
- 5.2 Avoid distorting, bending or cracking the specimens during and after removal from pavements or molds. Store the specimens in a cool place.
- 5.3 Assure the specimens are free of foreign materials such as seal coat, tack coat, soil, paper, or foil. Remove any of these materials when they are visually evident with a saw or by any other satisfactory means.

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- 5.4 For roadway cores, the sample size and number of samples must conform to the requirements of Tex-222-F.
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6. PROCEDURES

- 6.1 For specimens containing moisture, follow the instructions in Sections 6.2 – 6.10. For laboratory-molded specimens, perform the instructions in Sections 6.9 – 6.10 followed by Sections 6.2 – 6.6.
- 6.2 Attach the **suspension** apparatus to the scale and submerge in water. Tare the scale with the **suspension** apparatus submerged in water.
- 6.3 Immerse the specimen in a water bath at $77 \pm 3^{\circ}\text{F}$ ($25 \pm 2^{\circ}\text{C}$).
- 6.4 When the scale readings stabilize, record the specimen weight and designate as ‘C’ in **Section 7.1**.
- 6.5 Remove the specimen from water. Next, dry the surface of the specimen by blotting gently with a damp towel for no longer than 20 sec. To facilitate drying gently rotate the specimen while blotting if necessary, however do not shake, sling, or perform any action that removes water from within the specimen.
- 6.6 Weigh the specimen in air. Record as the saturated surface dry weight (SSD) and designate as ‘B’ in **Section 7.1**.
- 6.7 Proceed to **Section 6.8**. Or, as an option, predry the specimen using a vacuum device or air dry to partially remove excess moisture. To prevent damage to the vacuum sealing device (Corelok), wrap the specimen with a paper or cloth towel.
- 6.8 Place the specimen in an oven with the flat side of the specimen on a flat surface to complete the drying process. Oven-dry the specimen for a minimum of 2 hr. at a temperature no higher than $140 \pm 5^{\circ}\text{F}$ ($60 \pm 3^{\circ}\text{C}$) and no lower than $125 \pm 5^{\circ}\text{F}$ ($52 \pm 3^{\circ}\text{C}$) to constant weight. ‘Constant weight’ is defined as the weight at which further oven drying does not alter the weight by more than 0.05% in a 2-hr. or longer drying interval.
- Note 1**—Oven drying temperature can be reduced to a temperature no lower than 100°F (38°C) provided that the specimen remains in the oven for a minimum of 8 hr.
- Note 2**—As an option, for specimens not subject to further testing and evaluation, rapid dry in an oven at a temperature exceeding 140°F (60°C), but not to exceed 350°F (177°C) for a maximum of 12 hr. to constant weight.
- 6.9 Allow the specimen to cool then weigh in air to the nearest 0.1 g.
- 6.10 Record and designate this weight as ‘A’ in **Section 7.1**.

7. CALCULATIONS

- 7.1 Use the following calculations to determine G_a and percent of water absorbed by the specimen:

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

where:

- G_a = bulk specific gravity
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.

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

- 7.2 If the percent absorption exceeds 2%, then use the preferred method, Part VI. If the equipment is not available for this method, then use the alternative Part II.

PART II—BULK SPECIFIC GRAVITY OF COMPACTED BITUMINOUS MIXTURES USING PARAFFIN

8. SCOPE

- 8.1 Use this procedure for absorptive mixtures, which have more than 2.0% water absorption.

9. APPARATUS

- 9.1 *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
- 9.2 *Water Bath*—for immersing the specimen in water while suspended, equipped with an overflow outlet for maintaining a constant water level
- 9.3 *Mercury Thermometer*—marked in 1°F (0.5°C) divisions or digital thermometer capable of measuring the temperature specified in the test procedure
- 9.4 *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 15 oz. (500 mL).

10. TEST SPECIMENS

- 10.1 Test specimens may be laboratory-molded mixtures, cores, or slabs obtained from bituminous pavements.
- 10.2 Avoid distorting, bending, or cracking of the specimens during and after removal from pavements or molds. Store the specimens in a safe, cool place.
- 10.3 Assure that specimens are free of foreign materials such as seal coat, tack coat, soil, paper, or foil. Remove any of these materials when they are visually evident with a saw or by any other satisfactory means.
- 10.4 For roadway cores, the sample size and number of samples must conform to the requirements of Tex-222-F.
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11. MATERIALS

- 11.1 Use paraffin wax with an approximate melting point of 120°F (50°C).
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12. PROCEDURES

- 12.1 Follow the instructions in Sections 12.1.1 – 12.1.9 if the G_p is unknown. If the manufacturer provides the G_p , proceed to Section 12.2.
- 12.1.1 Weigh the sealed glass bulb in air. Record and designate this weight as ‘D’ in Section 13.1.
- 12.1.2 Determine the type of apparatus to use to weigh the samples suspended in water. Apparatus options are nonabsorptive string and a metal bucket or cage attached to the scale with a metal wire or a nonabsorptive string.
- 12.1.3 Attach the apparatus to the scale and submerge in water. Tare the scale with the apparatus submerged in water.
- 12.1.4 Submerge the bulb in water at $77 \pm 3^\circ\text{F}$ ($25 \pm 2^\circ\text{C}$) and weigh to the nearest 0.1 g. Record and designate this weight as ‘E’ in Section 13.1.
- 12.1.5 Heat approximately 5 lb. (2.5 kg) of paraffin in a 1 gal. (4 L) can until completely melted.
- 12.1.6 Allow the paraffin to cool after melting until a very thin film forms across the surface.
Note 3—Lightly blow across the surface of the paraffin to determine if a very thin film forms. This film will form only at the spot where your breath touches the paraffin surface.
- 12.1.7 Dip the sealed glass bulb into the prepared paraffin and withdraw immediately. Allow the paraffin on the bulb to cool and recoat the bulb with paraffin two more times.
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- 12.1.8 Weigh the paraffin-coated bulb, in air, to the nearest 0.1 g. Record and designate the weight as 'F' in Section 13.1.
- 12.1.9 Submerge the paraffin-coated bulb in water at a temperature of $77 \pm 3^{\circ}\text{F}$ ($25 \pm 2^{\circ}\text{C}$) and weigh to the nearest 0.1 g. Record and designate the weight as 'G' in Section 13.1.
- 12.2 To determine the G_a of compacted bituminous mixtures using paraffin follow the instructions in Sections 12.2.1 – 12.2.7.
- 12.2.1 Oven-dry the specimen at a maximum temperature of $140 \pm 5^{\circ}\text{F}$ ($60 \pm 3^{\circ}\text{C}$) to constant weight, which is defined as the weight at which further oven drying does not alter the weight by more than 0.05% in a 2-hr. or longer drying interval. 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' in Section 13.2. Refer to Notes 1 and 2 from Part I.
- 12.2.2 Prepare the melted paraffin as described in Sections 12.1.5 and 12.1.6. Coat the specimen by dipping it into paraffin three times. Allow the paraffin coating to cool and solidify between each coating.
- 12.2.3 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' in Section 13.2.
- 12.2.4 Determine the type of apparatus to use to weigh the samples suspended in water. Apparatus options are nonabsorptive string and a metal bucket or cage attached to the scale with a metal wire or a nonabsorptive string.
- 12.2.5 Attach the apparatus to the scale and submerge in water. Tare the scale with the apparatus submerged in water.
- 12.2.6 Completely submerge the suspended paraffin-coated specimen in water at $77 \pm 3^{\circ}\text{F}$ ($25 \pm 2^{\circ}\text{C}$).
- 12.2.7 Weigh the paraffin-coated specimen in water. Record and designate this weight as 'C' in Section 13.2. Immerse the specimen for a short time in hot tap water if it is necessary to remove the paraffin coating after determining the G_a . Remove the cord and peel the paraffin off the specimen.
- Note 4**—An option is to lightly dust the specimen with powdered talc before paraffin coating to facilitate paraffin removal.
- 12.3 Do not use the results calculated in this test procedure if this method yields a G_a that is greater than the G_a calculated in Part I.
- Note 5**—Use the results calculated in Part I when this occurs.

13. CALCULATIONS

13.1 Calculate G_p using the following formula:

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

Where:

G_p = specific gravity of paraffin

D = weight of bulb in air, g

E = weight of bulb in water, g

F = weight of paraffin coated bulb in air, g

G = weight of paraffin coated bulb in water, g.

13.2 Calculate G_a 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 of specimen in air, g

B = weight of paraffin-coated specimen in air, g

C = weight of paraffin-coated specimen in water, g

G_p = specific gravity of paraffin.

PART III—DETERMINING IN-PLACE DENSITY OF COMPACTED BITUMINOUS MIXTURES (NUCLEAR METHOD)

14. SCOPE

14.1 Use this procedure to determine the in-place density of compacted bituminous mixtures using a nuclear density gauge.

15. APPARATUS

15.1 *Nuclear Density Gauge*

15.2 *Portable Reference Standard*

15.3 *Calibration Curves for the Nuclear Gauge*

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- 15.4 *Scraper Plate and Drill Rod Guide*
- 15.5 *Drill Rod and Driver or Hammer*
- 15.6 *Shovel, Sieve, Trowel, or Straightedge and Miscellaneous Hand Tools*
- 15.7 *Gauge Logbook.*
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16. STANDARDIZATION

- 16.1 To standardize the nuclear density gauge, turn on the apparatus and allow it to stabilize.
Note 6—Follow the manufacturer’s recommendations in order to ascertain the most stable and consistent results.
- 16.2 Perform standardization with the apparatus located at least 25 ft. (8 m) away from other sources of radioactivity. Clear the area of large masses or other items that may affect the reference count rate.
Note 7—The preferred location for standardization checking is the pavement location tested. This is the best method for determining day-to-day variability in the equipment.
- 16.3 Take a minimum of four repetitive readings using the ‘**Reference Standard**,’ in **Section 16.6**, at the normal measurement period and determine the average of these readings.
Note 8—One measurement period of four or more times the normal period is acceptable if available on the apparatus. This constitutes one standardization check.
- 16.4 Detect the total number of gammas during the time period by determining the count per measurement period. Correct the displayed value for any prescaling built into the instrument.
Note 9—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 .
- 16.5 Use the value of N_s to determine the count ratios for the current day's use of the instrument.
Note 10—Perform another standardization check if for any reason the measured density becomes suspect during the day's use.

- 16.6 The following table lists the required actions to take based on the results from **Section 16.3**.

Table 2—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.

17. CALCULATIONS

- 17.1 Use these calculations **in Section 16.3**. 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.

18. PROCEDURE

- 18.1 To determine the in-place density using a nuclear density gauge, select an area that is relatively free of loose material, voids, or depressions.
Note 11—Select an area at least 12 in. (0.3 m) away from surface obstructions such as curbing, etc. **It is optional to use fine sand to fill any voids or minor depressions.**
 Avoid elevating the gauge above the surface of the material to be tested.
- 18.2 Measure the density of the selected area in either the backscatter or direct transmission mode.
Note 12—The direct transmission method is only applicable for lifts greater than 2 in. (50 mm) thick.
- 18.3 Follow the instructions in **Sections 18.3.1 – 18.3.2** to measure the in-place density of compacted bituminous pavements using a nuclear density gauge in the backscatter mode.

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- 18.3.1 Firmly seat the density gauge on the selected area so it is in full contact with the surface.
- 18.3.2 Record the readings that are required at each location with the probe in the backscatter position. Do not leave the gauge in one position on the compacted bituminous pavement for a long time as erratic readings may result from the hot surface. Proceed to **Section 18.5**.
- 18.4 Follow the instructions in **Sections 18.4.1 – 18.4.4** to measure the in-place density of compacted bituminous pavements using a nuclear density gauge in the direct transmission mode.
- 18.4.1 Make a hole 2 in. (50 mm) deeper than the transmission depth used with the drive pin and guide plate.
Note 13—The hole must be as close as possible to 90° from the plane surface.
- 18.4.2 Firmly seat the density gauge on the prepared area so it is in full contact with the surface.
- 18.4.3 Adjust the probe to the desired transmission depth. Pull the gauge so the probe is in contact with the side of the hole nearest the detector tubes.
- 18.4.4 Measure and record the readings that are required for each location for the particular type of gauge used. Proceed to **Section 18.5**.
- 18.5 Use one of the following methods to determine the in-place density.
- 18.5.1 Divide the field counts by the standard counts.
OR
- 18.5.2 Use the appropriate calibration curves, if necessary.
Note 14—Most models are now programmable to provide direct reading of the nuclear density or percent compaction.
- 18.6 Take cores or sections of the pavement from the same area selected for the nuclear tests when correlating the nuclear density to the actual density of the compacted material.
- 18.7 Measure the G_a of the cores or samples taken from the selected area tested for density as described in Part I, Part II, or Part **VI**. Establish a correlation factor using a minimum of seven core densities and seven nuclear densities. Adjust the nuclear density readings using this correlation factor to correlate with the actual G_a determined through laboratory testing.
Note 15—When testing thin lifts in the backscatter 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.
- 18.8 Make correlations as described in **Section 18.6** and compare the correlated nuclear density to the G_r or G_{rc} of the mixture when controlling in-place density with the nuclear gauge. Calculate the percent density or directly read from programmable models to determine air-void content.
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PART IV—ESTABLISHING ROLLER PATTERNS (CONTROL STRIP METHOD)

19. SCOPE

19.1 Use this procedure to establish roller patterns for bituminous pavement.

20. APPARATUS

20.1 *Nuclear Density Gauge*

20.2 *Electrical Impedance (Nonnuclear) Measurement Gauge (Optional)*

20.3 *Portable Reference Standard*

20.4 *Calibration Curves for the Nuclear Gauge*

20.5 *Scraper Plate and Drill Rod Guide*

20.6 *Drill Rod and Driver or Hammer*

20.7 *Shovel, Sieve, Trowel, or Straightedge and Miscellaneous Hand Tools*

20.8 *Gauge Logbook.*

21. PROCEDURE

21.1 To establish roller patterns (control strip method), refer to the gauge manufacturer's instructions for operating the density gauge.

Note 16—Standardize the equipment at the start of each day's use as described in Part III when using a nuclear density gauge.

21.2 Establish a control strip approximately 300 ft. (90 m) long and at least 12 ft. (3.5 m) wide or the width of the paving machine. Select three test sites.

Note 17—Avoid areas near edges or overlap of successive passes of the rollers.

21.3 Allow the roller to complete a minimum of two coverages of the entire control strip before checking the density. Perform density tests at the three test sites selected. Record the results. Mark each test site very carefully so that subsequent tests made are in the same position and location. Use a colored marker keel to outline the gauge before taking the readings. Take the tests as quickly as possible and release rollers to complete additional coverage to prevent cooling of unrolled areas.

21.4 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.

Note 18—In-place density determined with roadway cores is the final measure of rolling pattern effectiveness.

- 21.5 Construct another section, without interruption, using the roller patterns and number of coverages determined by the control strip after completion of the control strip tests. Take random density tests on this section to verify the results from the control strip.

Note 19—It may be possible to reduce the required coverages based on these tests.

- 21.6 Make density tests for job control according to the [Guide Schedule for Sampling and Testing](#) or as often as necessary, when some changes in the compacted material indicate the need.

22. NOTES

- 22.1 Visual observation of the surface being compacted is a very important part of this procedure. Cease rolling and get an evaluation of the roller pattern if obvious signs of distress develop, such as, cracking, shoving, etc. Structural failures, due to over compaction, will cause the density tests to indicate the need for more compaction. Observe closely and take particular care when using vibratory rollers since they are more likely to produce over compaction in the material.
- 22.2 Use the minimum test time allowed by the particular gauge when measuring density on hot material, since the gauge may display erratic results if it is overheated.
- 22.3 Exercise particular care to clean the bottom of the gauge after using it on asphalt pavement.
- 22.4 Use the correlation procedures outlined in [Part III, Section 18.7](#) when using specified density and rolling patterns.
- 22.5 This procedure provides a general guide to establish roller patterns. Follow the manufacturer's 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 the Department.
- 22.6 Nuclear gauges and the user of the nuclear gauges must meet all requirements of the Department's radioactive material license, "Nuclear Gauge Operating Procedures," and the *Texas Rules for Control of Radiation*.

PART V—DETERMINING MAT SEGREGATION USING A DENSITY-TESTING GAUGE

23. SCOPE

- 23.1 Use this procedure to identify segregation in bituminous pavements after placement on the roadway using a density-testing gauge.

24. APPARATUS

- 24.1 *Nuclear Density Gauge*
 - 24.2 *Thin Lift Density Gauge (Optional)*
 - 24.3 *Electrical Impedance (Nonnuclear) Measurement Gauge (Optional)*
 - 24.4 *Measuring Tape (Optional).*
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25. FORMS

- 25.1 [‘Segregation Density Profile Form.’](#)
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26. PROCEDURE

- 26.1 Refer to the manufacturer’s instructions for operating the density gauge.
Note 20—It is not necessary to calibrate the gauge to the mix.
 - 26.2 Profile a 50 ft. (15 m) section of the bituminous pavement.
 - 26.3 When profiling a location where the paver stopped, perform the instructions in 26.3.1 – 26.3.3.
 - 26.3.1 Identify the location where the paver stopped paving, such as sporadic mix delivery.
 - 26.3.2 Move approximately 10 ft. (3 m) behind the location where the paver stopped paving and mark and record this location as the beginning of the profile section.
 - 26.3.3 Proceed to Section 26.6.
 - 26.4 When profiling a random location, randomly select an area. Then choose an area with visible segregation, if possible. Proceed to Section 26.6.
 - 26.5 When profiling an area with segregation of longitudinal streaking greater than the profile length, follow the instructions shown in 26.5.1 – 26.5.5.
 - 26.5.1 Profile the area at an angle in a diagonal direction.
 - 26.5.2 Start the profile with a transverse offset of 2 ft. (0.6 m) from the center of the longitudinal streak.
 - 26.5.3 End profile with a transverse offset of 2 ft. (0.6 m) on the opposite side of the longitudinal streak.
 - 26.5.4 Do not start or end a profile less than 1 ft. (0.3 m) from the pavement edge.
 - 26.5.5 Proceed to Section 26.7.
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- 26.6 Determine the transverse offset 2 ft. (0.6 m) or more from the pavement edge. Take density readings in a longitudinal direction and do not vary from this line. Visually observe the mat and note the surface texture in the section and the location of any visible segregated areas. Take additional readings along the transverse offset in areas with visible segregation. Include any visually segregated areas in the profile.
- 26.7 After completion of the final rolling patterns, position the density gauge at the identified location.
- 26.7.1 *Use of a Nuclear Density Gauge:*
- 26.7.1.1 Take three 1 min. readings (minimum time length, longer readings can be used) in backscatter mode when using a nuclear density gauge at each random sample location.
- 26.7.1.2 It is optional to use fine sand passing the No. 40 sieve size to fill any voids without elevating the gauge above the rest of the mat.
- 26.7.2 *Use of an Electrical Impedance Gauge:*
- 26.7.2.1 Take two readings; it is not necessary to move the gauge between readings.
- 26.8 **Record the in-place density gauge readings.**
- 26.9 Average the readings before moving the density gauge. Compare each individual reading to the average. Discard any single readings that vary more than 1 **pcf (16 kg/m³)** from the average. Take additional readings to replace the discarded readings until all the readings are within 1 **pcf (16 kg/m³)** of the average.
- 26.10 Move the density gauge approximately 5 ft. (1.5 m) forward in the direction of the paving operation. Take an additional set of readings at any location with visible segregation in between the 5 ft. (1.5 m) distance.
- 26.11 Repeat **Sections 26.7 – 26.10**. Complete a minimum of ten sets of readings.
Note 21—Use a nuclear density gauge to verify impedance gauge readings whenever readings from an impedance gauge may not be accurate.
- 26.12 Determine the average density from all locations.
- 26.13 Determine the difference between the highest and lowest average density.
- 26.14 Determine the difference between the average and lowest average density.
- 26.15 Record the data using the example of '[Segregation Profile Worksheet](#).'
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PART VI—BULK SPECIFIC GRAVITY OF COMPACTED BITUMINOUS MIXTURES USING THE VACUUM METHOD

27. SCOPE

- 27.1 Use this procedure to determine the G_a of compacted bituminous mixtures using the vacuum device. This procedure is applicable for open and gap graded mixtures such as permeable friction course (PFC), coarse matrix high binder (CMHB), stone matrix asphalt (SMA), Superpave, and any other mixtures that have more than 2.0% water absorption by volume.

28. APPARATUS

- 28.1 *Specialized Vacuum Sealing Device*
- 28.2 *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
- 28.3 *Water Bath*—for immersing the specimen in water while suspended from a scale, equipped with an overflow outlet for maintaining a constant water level.

29. TEST SPECIMENS

- 29.1 Test specimens may be laboratory-molded mixtures, pavement cores, or pavement slabs.
- 29.2 Avoid distorting, bending or cracking the specimens during and after removal from pavements or molds. Store the specimens in a cool place.
- 29.3 Specimens must be free of foreign materials such as seal coat, tack coat, soil, paper, or foil. Remove any of these materials when they are visually evident with a saw or by any other satisfactory means.
- 29.4 For roadway cores, the sample size and number of samples must conform to the requirements of Tex-222-F.

30. MATERIALS

- 30.1 Use the supply of large (approximately 16 in. × 16 in. (410 mm × 410 mm)) and small (approximately 14 in. × 10 in. (360 mm × 250 mm)) specialized polymer bags provided by the manufacturer.

31. PROCEDURES

- 31.1 Perform the vacuum device setup as follows:

- 31.1.1 Set the vacuum timer.
Note 22—The manufacturer calibrates the vacuum pump timer setting and exhaust at the factory to eliminate drift and variability due to the sealing process. The vacuum pump operates for approximately 1 min. Contact the manufacturer for adjustments if the vacuum pump stops before this time has elapsed.
- 31.1.2 Set the sealing bar timer in accordance with the vacuum device manufacturer's recommendations.
Note 23—Inspect the seal quality after the first sealing operation. Reduce the setting if the polymer bag stretches or burns. Increase the setting if the seal is not complete or the bag easily separates.
- 31.2 **Determine** the G_a of compacted bituminous mixtures as follows:
- 31.2.1 Perform the instructions in **Sections 31.2.1.1 – 31.2.2** for specimens containing moisture.
- 31.2.1.1 Oven-dry the specimens that contain moisture at a maximum temperature of $140 \pm 5^\circ\text{F}$ ($60 \pm 3^\circ\text{C}$) to a constant weight, which is defined as the weight at which further oven drying does not alter the weight by more than 0.05% in a 2-hr. **or longer drying** interval. **Refer to Notes 1 and 2 from Part I.**
- 31.2.1.2 Allow the specimen to cool to room temperature, and then weigh in air to the nearest 0.1 g. Record and designate this weight as 'A' in **Section 32.1**. Proceed **to Section 31.2.3**.
- 31.2.2 Perform the instructions in **Section 31.2.2.1** if testing laboratory-molded specimens or dry specimens.
- 31.2.2.1 Allow laboratory-molded specimens or thoroughly dry specimens to cool to room temperature, then weigh the specimen in air to the nearest 0.1 g. Record and designate this weight as 'A' in **Section 32.1**. Proceed to **Section 31.2.3**.
- 31.2.3 Open the lid of the vacuum device. Stack or remove rectangular spacer plates in the vacuum chamber of the vacuum device so there is adequate space for the test specimen.
- 31.2.4 Place a sliding plate in the vacuum chamber on top of the spacer plates away from the seal bar.
Note 24—Place the sliding plate in the chamber to reduce friction during the sealing operation.
- 31.2.5 Select a large or small polymer bag to use to seal the specimen.
- 31.2.5.1 Use a large polymer bag for specimens with a diameter of 6 in. (152.4 mm) and a height or thickness greater than 2 in. (50.8 mm) i.e., Superpave gyratory molded specimens or field cores greater than 2 in. (50.8 mm) thickness.
- 31.2.5.2 Use a small polymer bag for specimens with a diameter of 4 in. and 6 in. (101.6 mm and 152.4 mm) and a height or thickness less than 2 in. (50.8 mm).
- 31.2.6 Weigh the selected polymer bag and record and designate this weight as 'B' in **Section 32.1**.

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- 31.2.7 Determine the polymer bag 'Correction Factor' (CF) as follows:
- 31.2.7.1 Calculate the ratio, 'R,' by dividing the weight of the specimen by the weight of the bag.
- 31.2.7.2 Use the CF Table provided in the manufacturer's operator guide.
- 31.2.7.3 Look up the calculated 'R' value and record and designate the corresponding correction factor from the table as 'CF.'
- 31.2.8 Perform **the instructions in Sections 31.2.8.1 – 31.2.8.6** to vacuum seal the specimens.
- 31.2.8.1 Place the bag inside the chamber.
- 31.2.8.2 Place the specimen in the polymer bag carefully avoiding punctures and tearing of the polymer bag.
- 31.2.8.3 Center the core in the bag leaving approximately 1 in. (25.4 mm) of slack on the backside.
- 31.2.8.4 Position the bag so that approximately 1 in. (25.4 mm) of the open end of the bag is evenly against the sealing bar.
- 31.2.8.5 Close the lid of the vacuum device and hold firmly for 2 to 3 sec.
Note 25—The vacuum pump will start and the lid will stay closed on its own. The vacuum gauge will read a vacuum less than **28 in. (50 mm)-Hg**.
- 31.2.8.6 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 the seal is tightly conformed to the specimen. **Return** to the instructions in **Section 31.2.6** if the seal is not tightly conformed to the specimen.
Note 26—A loose seal may be an indication of a leak.
- 31.2.9 Determine the type of apparatus to use to weigh the samples suspended in water.
- 31.2.10 Attach the apparatus to the scale and submerge in water. Tare the scale with the apparatus submerged in water.
- 31.2.11 Completely submerge the sealed specimen in water at $77 \pm 3^{\circ}\text{F}$ ($25 \pm 2^{\circ}\text{C}$) and record the weight of the specimen in the bag.
Note 27—Do not allow the polymer bag to 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' in **Section 32.1**.
- 31.2.12 Remove the specimen from the polymer bag and reweigh the specimen in air. Compare this weight to the weight recorded for 'A' in **Section 31.2.1 or 31.2.2**.
If the difference in weight is greater than 5 g, a leak may have occurred, dry the sample to a constant weight and repeat the procedure with a new polymer bag.
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- 31.3 Do not use the test results calculated in this test procedure using the vacuum device if this method produces a G_a that is higher than the G_a calculated in Part I.
Note 28—Use the results calculated in Part I of this method in this case.

32. CALCULATIONS

- 32.1 Calculate the G_a of the compacted specimen using the following formula.

$$G_a = \frac{A}{[(A + B) - C] - \frac{B}{CF}}$$

Where:

- G_a = bulk specific gravity
A = weight of specimen in air, g
B = weight of the polymer bag in air, g
C = weight of sealed specimen in water, g
CF = correction factor.

PART VII—DETERMINING LONGITUDINAL JOINT DENSITY USING A DENSITY-TESTING GAUGE

33. SCOPE

- 33.1 Use this procedure to perform a longitudinal joint density evaluation on bituminous pavement using a density-testing gauge.

34. APPARATUS

- 34.1 *Nuclear Density Gauge*
34.2 *Thin Lift Density Gauge (Optional)*
34.3 *Electrical Impedance (Nonnuclear) Measurement Gauge (Optional)*
34.4 *Measuring Tape (Optional).*

35. FORMS

- 35.1 [‘Longitudinal Joint Density Profile Form.’](#)

36. PROCEDURES

- 36.1 Perform a longitudinal joint density using a density-testing gauge as follows:
- 36.1.1 Refer to the manufacturer's instructions for operating the density gauge.
- 36.1.2 Identify the random sample location selected for in-place air void testing. Mark and record this location as the reference point to perform the joint evaluation.
Note 29—This point must be more than 2 ft. (0.6 m) from the pavement edge.
- 36.1.3 Position the gauge at the random sample location selected for in-place air void testing identified in **Section 36.1.2** after completion of the final rolling pattern.
- 36.1.3.1 *Use of a Nuclear Density Gauge:*
- 36.1.3.1.1 Take three 1 min. readings (minimum time length, longer readings can be used) in backscatter mode when using a nuclear density gauge.
- 36.1.3.1.2 It is optional to use fine sand passing the No. 40 sieve size to fill any voids without elevating the gauge above the rest of the mat.
- 36.1.3.2 *Use of an Electrical Impedance Gauge:*
- 36.1.3.2.1 Take two readings; it is not necessary to move the gauge between readings.
- 36.1.4 Record the density measurements from the density gauge at the random sample location selected for in-place air void testing.
- 36.1.5 Measure the longitudinal joint density at the right and left edge of the mat, which is or will become a longitudinal joint.
Note 30—Select a location that is perpendicular to the random sample location selected for in-place air void testing.
Identify the joint type as 'Confined' or 'Unconfined.'
Note 31—Take additional readings along the longitudinal joint at areas with visible irregularities or segregation.
- 36.1.6 Position the gauge with the center of the gauge placed 8 in. (**200 mm**) from the pavement edge that is or will become a longitudinal joint. Orient the gauge so the longer dimension of the gauge is parallel to the longitudinal joint.
- 36.1.6.1 *Use of a Nuclear Density Gauge:*
- 36.1.6.1.1 Take three 1 min. readings (minimum time length, longer readings can be used) in backscatter mode when using a nuclear density gauge.
- 36.1.6.1.2 It is optional to use fine sand passing the No. 40 sieve size to fill any voids without elevating the gauge above the rest of the mat.

- 36.1.6.2 *Use of an Electrical Impedance Gauge:*
- 36.1.6.2.1 Take two readings; it is not necessary to move the gauge between readings.
- 36.1.7 Record the density measurements from the density gauge at the longitudinal joint.
- 36.1.8 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 at the longitudinal joint.
- Note 32**—Use a nuclear density gauge to verify impedance gauge readings whenever readings from an impedance gauge may not be accurate.
- 36.1.9 Record and report the data using the example of the ‘[Longitudinal Joint Density Worksheet](#).’
- 36.2 Determine a correlated joint density as follows:
- 36.2.1 Measure the G_a of the cores taken from each random sample location selected for in-place air void testing according to Part I, II, or VI.
- 36.2.2 Record the G_r for each subplot evaluated for joint density.
- 36.2.3 Convert the subplot G_a and G_r to pounds per cubic foot by multiplying by the density of water [62.4 pcf \(1,000 kg/m³\)](#).
- 36.2.4 Determine the density gauge correlation factor.
- 36.2.4.1 Record the average density gauge reading at the interior mat random sample location for in-place air voids (a).
- 36.2.4.2 Record the average G_a in [pcf \(kg/m³\)](#) of the cores taken at the random sample location for in-place air voids (b).
- 36.2.4.3 Subtract the average density gauge reading (a) from the average G_a in [pcf \(kg/m³\)](#) of the cores (b).
- 36.2.5 Add this value to the density gauge readings at each location evaluated for joint density.
- 36.2.6 Record and report the data using the example of the ‘[Longitudinal Joint Density Worksheet](#).’

PART VIII—DETERMINING DENSITY OF PERMEABLE FRICTION COURSE (PFC) MIXTURES

37. SCOPE

- 37.1 Use this procedure to back-calculate the G_r of loose PFC mixtures, to calculate the G_a of laboratory-molded specimens for PFC mixtures using dimensional analysis, and to calculate density of compacted PFC mixtures.
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38. APPARATUS

- 38.1 Use a measuring device, such as a ruler, calipers, or measuring tape.
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39. PROCEDURE

- 39.1 To determine the density of a compacted PFC specimen, first back calculate G_r .
- 39.1.1 Obtain the G_e of the combined aggregate blend.
Note 33—Obtain the G_e from the Summary worksheet of the [Mix Design template](#).
- 39.1.2 Record and designate this as ' G_e ' in Section 40.1.
- 39.1.3 Determine the AC of the PFC mixture.
Note 34—Determine the AC of PFC-Asphalt Rubber (AR) mixtures by using the asphalt flow meter. Determine the AC of PFC PG 76 Mixtures using an ignition oven according to Tex-236-F or by using the asphalt flow meter
- 39.1.4 Record and designate this as ' A_s ' in Section 40.1.
- 39.1.5 Determine the specific gravity of the asphalt binder. Round to three decimal places (0.001).
- 39.1.6 Record and designate this as ' G_s ' in Section 40.1.
- 39.1.7 Calculate G_r as noted in Section 40.1.
- 39.2 Calculate G_a using dimensional analysis.
- 39.2.1 Measure the weight of the laboratory molded specimen in air, to the nearest 0.1 g.
- 39.2.2 Record and designate this weight as ' W ' in Section 40.2.
- 39.2.3 Measure the height of the laboratory-molded specimen, to the nearest 0.1 mm.
- 39.2.4 Record and designate this weight as ' h ' in Section 40.2.
- 39.2.5 Measure the diameter of the laboratory-molded specimen, to the nearest 0.1 mm.
-

- Note 35**—The diameter for specimens molded with a Superpave Gyrotory Compactor is 150 mm.
- 39.2.6 Calculate the radius of the laboratory molded specimen by dividing the diameter by two as determined in Section 39.2.5.
- Note 36**—The radius for specimens molded with a Superpave Gyrotory Compactor is 75 mm.
- 39.2.7 Record and designate this as 'r' in Section 40.2.
- 39.2.8 Calculate G_a as noted in Section 40.2.
- Note 37**—Numerical value for π is 3.14.
- 39.3 Calculate density of compacted PFC mixture.
- 39.3.1 Divide the G_a determined in Section 39.2.8 by the G_r determined in Section 39.1.7.
- 39.3.2 Multiply the results from Section 39.3.1 by 100.
- Note 38**—Round this calculated value to the tenth decimal place (0.1).

40. CALCULATIONS

- 40.1 Calculate the G_r of the loose PFC mixture using the following formula.

$$G_r = \frac{100}{\left[\left(\frac{100 - A_s}{G_e} \right) + \left(\frac{A_s}{G_s} \right) \right]}$$

Where:

G_r = theoretical maximum specific gravity

G_e = effective specific gravity, %

A_s = AC, %

G_s = asphalt binder specific gravity, 0.001.

- 40.2 Calculate the G_a of the compacted specimen using the following formula.

$$G_a = \frac{\left[\frac{W}{\pi r^2 h} \right]}{\gamma}$$

Where:

G_a = bulk specific gravity

W = weight of specimen, 0.1 g

π = pi, 3.14

r = radius of specimen, 1 mm

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- h = height of specimen, 0.1 mm
 γ = density of water, 0.001 g/mm³.
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41. REPORT FORMAT

- 41.1 Use the following Excel programs to calculate and report density test results.
- 41.1.1 [Quality Control/Quality Assurance \(QC/QA\)](#), used in conjunction with hot mix specification, test data worksheets for [1993/1995 Specifications](#) or for [2004 Specifications](#). Refer to the 'Help' tab for detailed instructions on how to use the program.
- 41.1.2 '[Segregation Density Profile Form](#)'
- 41.1.3 '[Longitudinal Joint Density Profile Form](#)'.
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42. ARCHIVED VERSIONS

- 42.1 Archived versions are available.