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

Overview

Effective date: August 1999 to October 2004.

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

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

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

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

Part IV is a procedure to establish roller patterns for bituminous pavement.

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.

Report Format

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

- 'Density of Compacted Specimens' worksheet (Densnew)
- QC/QA (used in conjunction with Hot Mix specification) test data worksheets (Newqcqa1). (Refer to the 'Help' tab for detailed instructions on how to use the program.)

Part I, Bulk Specific Gravity of Compacted Bituminous Mixtures

Use this part on all compacted bituminous mixtures except those with open or interconnecting voids and/or those which absorb more than 2.0 % water by volume.

Apparatus

The following apparatus is required:

- ♦ 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, capable of measuring the temperature specified in the test procedure and marked in 0.5 °C (1 °F) divisions
- ♦ 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 other satisfactory means.

Sample size and number of samples must conform to the requirements of Test Method "Tex-222-F, Sampling Bituminous Mixtures."

Procedure

The following steps provide the correct procedure for determining the density of compacted bituminous mixtures.

Use the 'Bulk Specific Gravity Specimens that Contain Moisture' table for specimens that contain moisture, such as roadway cores.

Bulk Specific Gravity Specimens that Contain Moisture

Step	Action
1	Tare the hook and line used to suspend specimen in water.
2	Suspend the specimen in water with a non-absorptive string of the smallest diameter available.
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.

Bulk Specific Gravity Specimens that Contain Moisture	
Step	**Action**
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 with hook and line. ♦ This is the Saturated Surface Dry Weight (SSD), designated as B under 'Calculations.'
6	Oven dry the specimen at 60 ± 3 °C (140 ± 5 °F) or air dry to constant weight.
7	Allow the specimen to cool then weigh in air.
8	Designate this weight as A under 'Calculations.' 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.

Use the 'Bulk Specific Gravity of Thoroughly Dry Specimens' procedure for specimens that 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. ♦ 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 specimen.

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

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

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%, then use 'Part II, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin.'

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

This part is used for absorptive mixtures which have more than 2.0 % water absorption.

Apparatus

The following apparatus is required:

- ♦ 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
- ♦ 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 free of foreign materials such as seal coat, tack coat, soil, paper or foil. visually evident, remove by sawing or other method which does not damage the specimens.
- ♦ Sample size and number of samples must conform to the requirements of Test Method "Tex-222-F, Sampling Bituminous Mixtures."

Materials

The following materials are needed:

- ♦ supply of 120-weight paraffin wax with a 50 °C (120 °F) melting point, approximately.

Procedure

The following steps provide the procedure to determine desired data on bulk specific gravity of compacted bituminous mixtures using paraffin.

- ♦ Determining Specific Gravity for Paraffin

Determining Specific Gravity for Paraffin

Step	Action
1	♦ Weigh the sealed glass bulb in air. ♦ Designate this weight as D under 'Calculations.'
2	♦ Submerge the bulb in water at 25 ± 2 °C (77 ± 3 °F) and weigh to the nearest 0.1 g. ♦ Designate this weight as E under 'Calculations.'
3	Heat approximately 2.5 kg (5 lbs.) of paraffin in a 4 L (1 gal.) can until completely melted.
4	♦ 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. ♦ This film will form only at the spot where your breath touches the paraffin surface.
5	♦ 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.
6	Weigh the paraffin coated bulb, in air, to the nearest 0.1 g and designate weight as F under 'Calculations.'
7	♦ 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. ♦ Designate the weight as G under 'Calculations.'

♦ 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 7 in the 'Determining Specific Gravity for Paraffin' procedure.
2	♦ Oven dry the specimen at 60 ± 3 °C (140 ± 5 °F) to constant weight. ♦ Weigh the dry specimen in air to the nearest 0.1 g. ♦ Designate this weight as A under 'Calculations.'
3	♦ Prepare the melted paraffin as described in steps 3 & 4 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	Weigh the paraffin-coated specimen in air to the nearest 0.1 g. Designate this weight as B under 'Calculations.'
5	Completely submerge the suspended paraffin-coated specimen in water at 25 ± 2 °C (77 ± 3 °F).
6	♦ Weigh the paraffin-coated specimen in water. ♦ 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. An option is to lightly dust the specimen with powdered talc prior to paraffin coating to facilitate paraffin removal.
7	♦ If this method yields a bulk specific gravity that is higher than the bulk specific gravity calculated using 'Part I, Bulk Specific Gravity of Compacted Bituminous Mixtures,' do not use the results calculated using 'Part II, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin.' ♦ In this case, revert to using the results calculated using '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:

- Gp = 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:

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

Where:

- Ga = 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
- Gp = Specific Gravity of paraffin.

Other Related Calculations

- Calculate the theoretical maximum specific gravity of the specimen:

$$G_t = \frac{100}{\frac{W}{G \, or \, G_e} + \frac{W_1}{G_1}}$$

Where:

- G_t = Theoretical maximum specific gravity of specimen
- W = Percent by weight of aggregate in specimen
- W_1 = Percent by weight of asphalt in specimen
- G = Average bulk specific gravity of the combined aggregate (see Test Method "Tex-201-F, Bulk Specific Gravity and Water Absorption of Aggregate")

- G_e = Effective specific gravity of the combined aggregate
- G_1 = Specific gravity of the asphalt determined at 25 °C (77 °F).

NOTE: G_e is used 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 (Test Method "Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures")
- G_{rc} = Theoretical maximum specific gravity, corrected (Test Method "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 (Test Method "Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures")
- G_{rc} = Theoretical maximum specific gravity, corrected (Test Method "Tex-227-F, 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.

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_1 = 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:

$$W = \frac{94.0}{98.7} \times 100 = 95.2$$

$$W_1 = \frac{4.7}{98.7} \times 100 = 4.8$$

$$95.2 + 4.8 = 100\%$$

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:

$$VMA = 100 - \frac{(G_a)}{G_r \text{ or } G_{rc}}(100) + \frac{G_a \times \%\,AC}{G_1}$$

Where:

- G_a = Average actual bulk specific gravity of three specimens compacted according to Test Method "Tex-206-F, Compacting Test Specimens of Bituminous Mixtures"
- G_r = Theoretical maximum specific gravity according to Test Method "Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures"
- %AC = Asphalt content
- G_1 = Specific gravity of asphalt
- G_{rc} = Theoretical maximum specific gravity of specimen, corrected (Test Method "Tex-227-F Theoretical Maximum Specific Gravity of Bituminous Mixtures").

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

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

Apparatus

The following apparatus is required:

- 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

Use the following procedure to standardize the nuclear testing gauge.

Standardizing Nuclear Testing Gauge

Step	Action
1	♦ Turn on the apparatus prior to standardization and allow it to stabilize. ♦ 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 and clear the area of large masses or other items which may affect the reference count rate. ♦ 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 mean. ♦ 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. ♦ The displayed value must be corrected 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.
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 procedure shows reference standard consequences in Step 3 of the 'Standardizing Nuclear Testing Gauge' procedure.

Reference Standard

If the. . .	then. . .
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.
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.
second standardization check is within the limits,	the apparatus may be used.
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

The following procedure provides for determining in-place density of compacted bituminous mixtures (Nuclear Method).

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 back scatter or direct transmission modes; however, the lift must be at least 51 mm (2 in.) thick to allow the use of direct transmission.
3	♦ 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.
4	When correlating the nuclear density to the actual density of the compacted material, take

Determining In-Place Density of Compacted Bituminous Mixtures (Nuclear Method)	
Step	**Action**
	cores or sections of the pavement from the same test area selected for the nuclear tests.
5	Test these cores or samples according to 'Part I' or 'Part II' of this test method to determine the actual specific gravity (G_a). ♦ Adjust the nuclear density as necessary to correlate with the (G_a) thus determined and introduce a factor into the nuclear device for observation of that actual density. ♦ At least seven core densities and seven nuclear densities must be used to establish a conversion factor. 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.
6	♦ When controlling in-place density with the nuclear gauge, make correlations as described in Step 4 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.

The following procedures provide parameters for density determinations in backscatter and direct transmission mode. (Refer to Step 2 of the 'Determining In-Place Density of Compacted Bituminous Mixtures [Nuclear Method]' procedure.)

- In-Place Density of Compacted Bituminous Mixtures (Nuclear Method) – Determinations in Backscatter Mode

In-Place Density of Compacted Bituminous Mixtures (Nuclear Method) Determinations in Backscatter Mode	
Step	**Action**
1	Place the gauge on the test area making sure that the base is firmly seated and in full contact with the surface.
2	♦ With the probe in the back-scatter position, record the number of readings required 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.

- In-Place Density of Compacted Bituminous Mixtures (Nuclear Method) – Determinations using Direct Transmission

In-Place Density of Compacted Bituminous Mixtures (Nuclear Method) – Determinations using Direct Transmission	
Step	**Action**
1	♦ 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.
2	Place the gauge on the prepared surface so that the base is firmly seated and in full contact with the surface.
3	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.
4	Record the number of readings required for the particular gauge being used.

Part IV, Procedure for Establishing Roller Patterns (Control Strip Method)

This part is a procedure to establish roller patterns for bituminous pavement.

Procedure

The following procedure provides parameters for establishing roller patterns by the control strip method.

Establishing Roller Patterns (Control Strip Method)	
Step	**Action**
1	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.
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 nuclear density. ♦ Perform density tests at the three test sites selected as described in 'Part III' of this test method. ♦ 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 as readings are being taken. ♦ To prevent cooling of unrolled areas, take the three 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 nuclear 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 nuclear 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, 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' are necessary.

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

The 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.