Test Procedure for

SUPERPAVE GYRATORY COMPACTING OF TEST SPECIMENS OF BITUMINOUS MIXTURES

TxDOT Designation: Tex-241-F

Effective Dates: July 2009–April 2010.

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1. SCOPE

1.1 This test method is used to:

1.1.1 Compact cylindrical specimens of hot-mix asphalt (HMA) using the Superpave gyratory compactor.

1.1.2 Prepare specimens for determining the mechanical and volumetric properties of HMA.

Note 1—The specimens simulate density, aggregate orientation, and structural characteristics obtained in the actual roadway when proper construction procedure is used in the placement of the paving mix.

1.1.3 Monitor the density of test specimens during their preparation and for field control of an HMA production process.

1.2 Refer to Table 1 when using Superpave specifications instead of standard department specifications. Replace Department nomenclature with Superpave nomenclature when required.

Table 1—Nomenclatures and Definitions

Nomenclatures		Definitions
Department	Superpave	
G_a	G_{mb}	Bulk specific gravity of the compacted mixture
G_r	G_{mm}	Theoretical maximum specific gravity

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. APPARATUS

2.1 *Superpave gyratory compactor (SGC).*

2.1.1 The compactor is an electrohydraulic or electromechanical compactor with a ram and ram heads that are restrained from revolving during compaction.

2.1.2 The axis of the ram is perpendicular to the platen of the compactor.

2.1.3 The compactor tilts the specimen molds at an angle of 22 ±0.35 mrad (1.25 ±0.02°) and gyrates specimen molds at a rate or 30.0 ±0.5 gyrations per minute throughout compaction.

2.1.4 The compactor is designed to permit the specimen mold to revolve freely on its tilted axis during gyration.

2.1.5 The ram applies and maintains a pressure of 600 ±18 kPa (87 ±2 psi) perpendicular to the cylindrical axis of the specimen during compaction.

Note 2—This stress calculates to 10,600 ±310 N (2,383 ±70 lb_f) total force for 150 mm (5.912 in.) specimens.

2.2 *Specimen height measurement and recording device.*

2.2.1 When monitoring specimen density during compaction, provide a means to continuously measure and record the height of the specimen to the nearest 0.1 mm during compaction, once per gyration.

2.2.2 The system may include a printer connected to an RS232C port capable of printing test information, such as specimen height per gyration. In addition to a printer, the system may include a computer and suitable software for data acquisition and reporting.

2.3 *Specimen molds.*

2.3.1 Specimen molds must have steel walls that are at least 7.5 mm (0.3 in.) thick and are hardened to at least Rockwell C48.

2.3.2 Molds must have an inside diameter of 149.90 to 150.00 mm (5.9 to 5.912 in.) and be at least 250 mm (10 in.) high.

2.3.3 The inside finish of the molds must have a root mean square (rms) of 1.60 µm or smoother.

Note 3—Smoothness measure is according to ANSI B46.1. One source of supply for a surface compactor, which is used to verify the rms value of 1.60 µm, is GAR Electroforming, Danbury, Connecticut.

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2.4 *Ram heads and mold bottoms.*

2.4.1 Ram heads and mold bottoms must be fabricated from steel with a minimum Rockwell hardness of C48.

2.4.2 The ram heads must be perpendicular to its axis.

2.4.3 The platen side of each mold bottom must be flat and parallel to its face.

2.4.4 All ram and base plate faces (the sides presented to the specimen) must be ground flat to meet smoothness requirement according to ANSI B 46.1 and must have a diameter of 149.5 to 149.75 mm (5.885 to 5.896 in.).

2.5 *Mercury thermometer*, marked in 3°C (5 ºF) divisions or less, or a digital thermometer, capable of measuring the temperature specified in this test procedure.

2.6 *Balance,* Class G2 in accordance with Tex-901K, with a minimum capacity of 10,000 g.

2.7 *Heating oven,* capable of maintaining a temperature of at least 163 ±3ºC (325 ±5ºF).

2.8 *Pans,* metal, with flat bottom.

2.9 *Scoop, spatula, trowel.*

2.10 *Paper disks.*

2.11 *Insulating gloves.*

2.12 *Lubricating materials.*

Note 4—Use standard safety precautions and protective clothing when handling hot asphalt mixtures and preparing test specimens.

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3. CALIBRATION

3.1 Items requiring periodic verification of calibration include:

- Ram pressure
- Angle of gyration
- Gyration frequency
- LVDT (or other means used to continuously record the specimen height)
- Oven temperature

3.2 Verification of the mold and platen dimensions and the inside finish of the mold are also required.

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3.3 When the computer and software options are used, periodically verify the data processing system output using a procedure designed for such purposes.

3.4 The manufacturer, other agencies providing such services, or in-house personnel may perform the verification of the calibration system standardization and quality checks. Frequency of verification must follow manufacturer's recommendations.

4. PREPARATION OF THE SGC

4.1 Warm up the compactor before the asphalt concrete mixture is ready for placement in the mold.

4.2 Verify settings for angle, pressure, and number of gyrations.

4.3 Lubricate bearing surfaces as needed.

4.4 Lubricate the surface of the rotating base and the surface of the four rollers.

4.5 Follow the instructions in Sections 4.5.1–4.5.2 when monitoring the specimen height.

4.5.1 Before placing the material in the mold, turn on the device for measuring and recording the height of the specimen. Verify that the readout is in the proper units, mm, and the recording device is ready.

4.5.2 If using a computer, prepare it to record the height data and enter the header information for the specimen.

5. MIXTURE PREPARATION

5.1 For hot mix asphalt concrete (HMAC) laboratory-produced mixtures, proceed to Section 5.2. For HMAC plant-produced mixtures, proceed to Section 5.3. For laboratory or plant mixtures produced with Warm Mix Asphalt (WMA) additives or processes, proceed to Section 5.4.

5.2 *HMAC Laboratory-Produced Mixtures:*

5.2.1 Combine aggregates and prepare laboratory bituminous mixture as described in Tex-205-F.

5.2.2 Select a compaction temperature from Table 2 based on the asphalt binder used in the mixture design.

5.2.3 Oven-cure the mixture at the selected compaction temperature for 2 hours prior to molding.

5.2.4 Proceed to Section 5.5.

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5.3 *HMAC Plant-Produced Mixtures:*

5.3.1 Sample the plant-produced mixture in accordance with Tex-222-F.

5.3.2 Select the compaction temperature from Table 2 based on the asphalt binder used in the mixture design.

5.3.3 Oven-cure the mixture at the selected compaction temperature for a maximum of 2 hours prior to molding.

Note 5—Reduce or eliminate the two-hour curing when testing shows that it does not affect the material properties and the laboratory-molded density.

5.3.4 Proceed to Section 5.5.

5.4 *WMA Laboratory or WMA Plant-Produced Mixtures:*

5.4.1 Prepare the laboratory bituminous mixture in accordance with Tex-205-F or sample the plant-produced mixture in accordance with Tex-222-F.

5.4.2 Select a compaction temperature.

5.4.2.1 When WMA additives or processes are allowed, select the compaction temperature from Table 2 based on the asphalt binder used in the mixture design, unless otherwise recommended by the WMA material supplier and allowed by the Engineer.

Note 6—The compaction temperature may be reduced to the anticipated production temperature when allowed by the Engineer.

5.4.2.2 When WMA additives or processes are required, select the compaction temperature between 215°F and 275°F, as recommended by the WMA material supplier.

5.4.2.3 When compacting WMA mixtures for mechanical property testing, compact the specimens at 275 ±5ºF.

Note 7—Mechanical property testing may include the Hamburg Wheel-Tracking Test (Tex-242-F), Overlay Test (Tex-248-F), and Indirect Tensile Strength Test (Tex-226-F), as well as any other laboratory test used to measure and predict performance.

5.4.3 Oven-cure the WMA mixture at the selected compaction temperature for 2 hours except when molding specimens for mechanical property testing.

5.4.3.1 Oven-cure the WMA mixture intended for preparing specimens for mechanical property testing at 275 ±5ºF for 4 hours prior to molding.

5.4.4 Proceed to Section 5.5.

5.5 Select a mixture weight based on the ultimate disposition of the test specimens.

5.5.1 If a target air void level is desired, as would be the case for Superpave performance specimens, adjust the material weight to create a given density in a known volume.

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5.5.2 If using the specimens to determine volumetric properties, adjust the material weight to result in a compacted specimen having dimensions of 150 mm (6 in.) in diameter and 115 ±5 mm (4.5 ±0.2 in.) in height at the design number of gyrations.

Note 8 —It may be necessary to produce a trial specimen to achieve this height requirement. Generally, 4500–4700 g of aggregate are required to achieve this height for aggregates with combined bulk specific gravities of 2.55–2.70, respectively.

5.6 Place a compaction mold base plate and the top plate in an oven at the selected compaction temperature 60 ±15 min. before compaction.

6. MIXING AND COMPACTION TEMPERATURES

6.1 Use Table 2 when preparing the samples for mixing and compaction. Use the same temperature for both curing and compaction of samples with the respective binder.

6.2 Mixtures containing asphalt materials not listed in Table 2, or those containing viscosity-modifying additives, may require considerably varied mixing temperatures from those listed. For guidance, consult the binder supplier or the Flexible Pavements Branch of the Materials and Pavements Section of the Construction Division.

6.3 The Engineer must approve the use of mixing and compaction temperatures different from those listed.

Table 2—Mixing and Compaction Temperatures

PG Grade	Mixing, °F	Compaction, °F
64 - 22	290	250
64 - 28	300	275
70 - 22	300	275
70 - 28	325	300
76 - 16	325	300
76 - 22	325	300
Asphalt Rubber (A-R)	325	300

Note 9—Mixtures must be compacted at the selected compaction temperature within a tolerance of ±5°F.

7. PROCEDURES

7.1 *Compaction:*

7.1.1 Use the design number of gyrations (N_{des}) for compaction as shown on the plans. When the N_{des} is not shown on the plans, use Table 3 as guidance or contact the Flexible

Pavements Branch of the Construction Division for recommendations. The numbers of gyrations provided in Table 3 are for guidance only.

Note 10—When the mixture appears dry and lacking asphalt, lower the N_{des} to increase the optimum asphalt content of the mixture. This technique will produce a mixture with more asphalt.

7.1.2 Following oven curing, remove the heated mold and base plate from the oven and place a paper disk on the bottom of the mold.

7.1.3 Place the mixture into the mold in one lift. Take care to avoid segregation in the mold.

7.1.4 After all the mix is in the mold, level the mix with a spatula and place another paper disk and the top plate on the leveled material.

7.1.5 Load the specimen mold with paving mix into the compactor and center the mold under the loading ram.

7.1.6 Lower the ram until the pressure on the specimen reached 600 ±18 kPa (87 ±2 psi).

7.1.7 Apply a 22.0 ±0.35 mrad (1.25 ±0.02°) angle to the mold assembly and begin the gyratory compaction.

7.1.8 Allow compaction to proceed until completion of the specified number of gyrations selected from Table 3 and until the gyratory mechanism shuts off.

7.1.8.1 When monitoring the specimen height, record the specimen height to the nearest 0.1 mm (0.004 in.) after each revolution.

7.1.9 Remove the angle from the mold assembly, raise the loading ram, remove the mold from the compactor, and extrude the specimen from the mold.

Note 11 —Do not immediately extrude the specimen from the mold for lean, rich, and tender mixtures, for mixtures containing asphalt rubber binder, or for mixtures compacted to a density less than 93% to prevent deformation of the specimen. Allow the mold to cool for approximately 10 min. or more in front of a fan.

7.1.10 Remove the paper disks from the top and bottom of the specimens.

Note 12—Before reusing the mold, place it in the oven for at least 5 min. The use of multiple molds will speed up the compaction process.

7.2 *Density:*

7.2.1 Determine the maximum specific gravity (G_r) of the loose mix in accordance with Tex-227-F using a companion sample. For permeable friction course (PFC) mixtures, back calculate G_r in accordance with Tex-207-F.

Note 13—Oven-cure the companion sample to the same extent as the compaction sample.

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7.2.2 Record the mass of the extruded specimen to the nearest gram and determine the bulk specific gravity (G_a) of the extruded specimen in accordance with Tex-207-F.

7.2.3 Calculate the relative density of the extruded specimen ($\%G_{mm}$) in accordance with Section 8.1.

7.2.3.1 When monitoring the specimen height, estimate the relative density of the specimen at any point in the compaction process in accordance with Section 8.2.

7.2.3.2 When monitoring the specimen height and using dimensional analysis, estimate the relative density of the specimen at any point in the compaction process in accordance with Sections 8.3 and 8.4.

Table 3—Compaction Parameters

Binders < PG 76-XX		**Binders ≥ PG 76-XX or HMA Placed > 4 inches from Surface**	
Design ESALs[1] (million)	**N_{des}[2]**	**Design ESALs[1] (million)**	**N_{des}[2]**
<0.3	50	<0.3	35
0.3 to <3	65	0.3 to <3	50
3 to <30	80	3 to <30	65
≥30	100	≥30	80

1. Design ESALs are the anticipated project traffic level expected on the design lane over a 20-yr. period.
2. Use the N_{des} for compaction as shown on the plans. When the N_{des} is not shown on the plans, use this table as guidance or contact the Flexible Pavements Branch of the Construction Division for recommendations. Lower the N_{des} to increase the optimum asphalt content of the mixture.

8. CALCULATIONS

8.1 Calculate $\%G_{mm}$:

$$\%G_{mm} = \frac{G_a}{G_r} * 100$$

Where:

$\%G_{mm}$ = relative density of the extruded specimen expressed as a percent of the theoretical maximum specific gravity

G_a = bulk specific gravity of the extruded specimen

G_r = theoretical maximum specific gravity of the mix.

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8.2 Estimate the percent compaction ($\%G_{mmx}$) at any point in the compaction process:

$$\%G_{mmx} = \frac{G_a h_m}{G_r h_x} \times 100$$

Where:

$\%G_{mmx}$ = relative density expressed as a percentage of the theoretical maximum specific gravity

G_a = bulk specific gravity of the extruded specimen

G_r = theoretical maximum specific gravity of the mix

h_m = height of the extruded specimen, mm

h_x = height of the specimen after "x" gyrations, mm.

8.3 Estimate the relative density at any point in the compaction process using dimensional analysis:

$$\%G_{mmx}(DimensionalAnalysis) = \frac{A}{V_{mx} G_r \gamma_w} \times 100$$

Where:

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

A = mass of the specimen, g

G_r = theoretical maximum specific gravity of the mix

γ_w = unit weight of water, 1 g/cm^3

V_{mx} = volume of the specimen, cm^3, at any point in the compaction process.

8.4 Calculate V_{mx}:

$$V_{mx} = \frac{\pi d^2 h_x}{4 \times 1000}$$

Where:

d = diameter of the specimen, mm

h = height of the specimen, mm

x = number of gyrations at which the measurement is being taken (subscript information only, not used in the calculations).

Note 14 —This formula gives volume in cm^3 to allow direct comparison with specific gravity.

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9. ARCHIVED VERSIONS

9.1 Archived versions are available.

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