Tex-241-F, Superpave Gyratory Compacting of Test Specimens of Bituminous Mixtures

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Section 1
Overview

Effective date: November 2005 (refer to 'Archived Versions' for earlier versions).

Use this test method to:

- compact cylindrical specimens of hot-mix asphalt (HMA) using the Superpave gyratory compactor;
- prepare specimens for determining the mechanical and volumetric properties of HMA. (The specimens simulate the density, aggregate orientation, and structural characteristics obtained in the actual roadway when proper construction procedure is used in the placement of the paving mix.); and
- monitor the density of test specimens during their preparation and for field control of an HMA production process.

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.

Section 2

Apparatus

Use the following apparatus:

- Superpave gyratory compactor
  - The compactor is an electrohydraulic or electromechanical compactor with a ram and ram heads that are restrained from revolving during compaction.
  - The axis of the ram is perpendicular to the platen of the compactor.
  - The compactor tilts the specimen molds at an angle of 22 ±0.35 mrad (1.25 ±0.02°) and gyrate specimen molds at a rate or 30.0 ±0.5 gyrations per minute throughout compaction.
  - The compactor is designed to permit the specimen mold to revolve freely on its tilted axis during gyration.
  - 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*: This stress calculates to 10,600 ±310 N [2,383 ±70 lb_f] total force for 150 mm [5.912 in.] specimens.)
- specimen height measurement and recording device
  - 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.
  - 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.
- specimen molds
  - Specimen molds must have steel walls that are at least 7.5 mm (0.3 in.) thick and are hardened to at least Rockwell C 48.
  - Molds must have an inside of 149.90 to 150.00 mm (5.9 to 5.912 in.) and be at least 250 mm (10 in.) high.
  - The inside finish of the molds must have a root mean square (rms) of 1.60 µm or smoother. (*NOTE*: Smoothness measure is according to ANSI B 46.1. 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.)
- ram heads and mold bottoms
  - Ram heads and mold bottoms must be fabricated from steel with a minimum Rockwell hardness of C 48.
  - The ram heads must be perpendicular to its axisR.

  - The platen side of each mold bottom must be flat and parallel to its face.
  - 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 149.50 to 149.75 mm (5.885 to 5.896 in.).

- mercury thermometer, marked in 1°C (2°F) divisions or a digital thermometer capable of measuring the temperature specified in this test procedure
- balance, readable to 0.1 g and accurate to 0.5 g
- oven, capable of maintaining a temperature of 60 ±3°C (140 ±37°F) or more
- pans, metal with flat bottom
- scoop, spatula, trowel
- large mixing spoon
- containers
- beakers
- grill-type tins
- paper disks
- gloves
- mechanical mixer
- lubricating materials.

NOTE: Use standard safety precautions and protective clothing when handling hot asphalt mixtures and preparing test specimens.

Section 3
Calibration

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), and
- oven temperature.

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

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

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

Section 4
Preparations

Preparing Apparatus

Follow these steps to prepare the apparatus.

Preparing Apparatus	
Step	**Action**
1	Warm up the compactor before the time when the asphalt concrete mixture is ready for placement in the mold.
2	Verify settings for angle, pressure, and number of gyrations.
3	Lubricate bearing surfaces as needed.
4	Lubricate the surface of the rotating base and the surface of the 4 rollers.
5	When monitoring the specimen height, the following preparation is required. ♦ Before placing the paving mix 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. ♦ If a computer is used, prepare it to record the height data and enter the header information for the specimen.

Preparing Sample

Follow these steps to prepare the sample.

Preparing Sample	
Step	**Action**
1	♦ Weigh the appropriate aggregate fractions into a separate pan and combine to the desired batch weight. The batch weight will vary based on the ultimate disposition of the test specimens. ♦ If a target air void level is desired, as would be the case for Superpave performance specimens, batch weights will be adjusted to create a given density in a known volume. ♦ If using the specimens to determine volumetric properties, the batch weights will be adjusted 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*: 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.
2	Place the aggregate and the asphalt binder in the oven and heat to the required mixing temperature.
3	Select mixing and compaction temperatures according to the performance grade (PG) of the asphalt binder used in the design. (See the 'Mixing and Compaction Temperatures' table.)
4	♦ Mix and thoroughly blend all sizes of the dry heated aggregate. ♦ Form a depression in the aggregate and weigh the required amount of asphalt binder into the mix.
5	Thoroughly mix the aggregate and asphalt binder with a mechanical mixer.
6	Place the loose mix in a shallow flat pan after completing the mixture preparation, and spread to an even thickness.
7	Place the shallow flat pan, with the loose mix, in an oven at the compaction temperature selected from Step 3 for 2 hr. to cure the mix.

Preparing Sample	
Step	**Action**
8	Place a compaction mold base plate and top plate in an oven at the selected compaction temperature from Step 3, 60 ±15 min. before compaction.
9	If loose HMA plant mix is used, bring the mixture to the compaction temperature range by careful uniform heating in an oven immediately before molding.

Use this table for mixing and compaction temperatures.

Mixing and Compaction Temperatures		
PG Grade	**Mixing**	**Compaction**
64 - 22	290	250
64 - 28	300	275
70 - 22	300	275
70 - 28	325	300
76 – 16	325	300
76 - 22	325	300

NOTE: Mixtures containing asphalt materials not listed above, or those containing viscosity-modifying additives, may require considerably varied mixing temperatures from those shown above. For guidance, consult the binder supplier or the Asphalt and Chemical Branch of the Materials and Pavements Section of the Construction Division. The engineer must approve the use of mixing and compaction temperatures different from those listed above.

Section 5
Procedures

Compaction

Follow these steps to compact the mixture.

Compaction	
Step	**Action**
1	Use the design number of gyrations (N_{des}) for compaction as shown on the plans or as specified in the 'Compaction Parameters' table. The numbers of gyrations provided in the 'Compaction Parameters' are provided for guidance only. NOTE: When the mixture appears dry looking and lacking of asphalt, lower the N_{des} to increase the optimum asphalt content of the mixture. This technique will produce a leaner mixture with more asphalt.
2	Following the short-term aging period, remove the heated mold and base plate from the oven and place a paper disk on the bottom of the mold.
3	♦ Place the mixture into the mold in one lift. Take care to avoid segregation in the mold. ♦ 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.
4	Load the specimen mold with paving mix into the compactor and center the mold under the loading ram.
5	Lower the ram until the pressure on the specimen reached 600 ±18 kPa (87 ±2 psi).
6	Apply a 22.0 ±0.35 mrad (1.25 ±0.02°) angle to the mold assembly and begin the gyratory compaction.
7	Allow compaction to proceed until completion of the specified number of gyrations selected from 'Compaction Parameters' and until the gyratory mechanism shuts off.
8	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*: Do not immediately extrude the specimen from the mold for lean, rich and tender mixtures or 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.
9	Remove the paper disks from the top and bottom of the specimens. *NOTE*: 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.

Density

Follow these steps, in addition to those specified in 'Preparing Sample,' when monitoring the specimen height.

Density	
Step	**Action**
1	♦ Determine the maximum specific gravity (G_r) of the loose mix according to "Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures," using a companion sample. ♦ Oven-cure or age the companion sample to the same extent as the compaction sample.
2	Record the specimen height to the nearest 0.1 mm (0.004 in.) after each revolution.

Density	
Step	**Action**
3	Record the mass of the extruded specimen to the nearest gram and determine the bulk specific gravity (G_a) of the extruded specimen according to "Tex-207-F, Determining Density of Compacted Bituminous Mixtures."

The following table lists the initial number of gyrations ($N_{initial}$), design number of gyrations (Ndes), and maximum number of gyrations ($N_{maximum}$).

Compaction Parameters				
Design ESALs[1] (million)	**Compaction Parameters**			**Typical Roadway Application[2]**
	$N_{initial}$	N_{des}	$N_{maximum}$	
<0.3	6	50	75	Applications include roadways with very light traffic volumes such as local roads, county roads, and city streets where truck traffic is prohibited or at a very minimal level. Traffic on these roadways is local in nature, not regional, intrastate, or interstate. Special purpose roadways serving recreational sites or areas may also be applicable to this level.
0.3 to <3	7	75	115	Applications include many collector roads or access streets. Medium-trafficked city streets and the majority of county roadways may be applicable to this level.
3 to <30	8	100	160	Applications may include many 2-lane, multilane, divided, and partially or completely controlled access roadways. Among these are medium to highly trafficked city streets, many state routes, US highways, and some rural interstates.
≥30	9	125	205	Applications include the vast majority of the US Interstate System, both rural and urban in nature. Special applications such as truck-weighing stations or truck-climbing lanes on 2-lane roadways may also be applicable to this level.

[1]Design ESALs are the anticipated project traffic level expected on the design lane over a 20-yr. period. Regardless of the actual design life of the roadway, determine the design ESALs for 20 yr., and choose the appropriate Ndes level.

[2]Typical Roadway Applications as defined by *A Policy on Geometric Design of Highway and Streets*, AASHTO.

Section 6
Calculations

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

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

Where:

- % Gmmx = uncorrected relative density at any point during compaction expressed as a percent of the theoretical maximum specific gravity
- A = mass of the specimen in grams
- 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, in cm^3, at any point based on the diameter (d) and height (hx) of the specimen at that point (use "mm" for height and diameter measurements). It can be expressed as:

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

Where:

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

NOTE: This formula gives volume in cm^3 to allow direct comparison with specific gravity.

At the completion of the bulk specific gravity test, determine the percent compaction (Gmmx) at any point in the compaction process as follows:

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

Where:

- % G_{mmx} = corrected 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 in millimeters of the extruded specimen
- h_x = height in millimeters of the specimen after "x" gyrations.

Section 7
Archived Versions

The following archived versions of "Tex-241-F, Superpave Gyratory Compacting of Test Specimens of Bituminous Mixtures" are available:

- 241-0899 for the test procedure effective August 1999 through January 2005
- 241-0205 for the test procedure effective February 2005 through June 2005
- 241-0705 for the test procedure effective July 2005
- 241-0805 for the test procedure effective August 2005 through October 2005.