Chapter 37

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

Contents:

Section 1

Overview

Effective dates: August 1999 – January 2005.

This method is used to provide a procedure for the compaction of cylindrical specimens of hot mix asphalt (HMA) using the Superpave gyratory compactor.

This procedure is used to 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. The test procedure may also be used to monitor the density of test specimens during their preparation. It may also be used 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

The following apparatus is required:

- ♦ Superpave Gyratory Compactor
  - an electrohydraulic or electromechanical compactor with a ram and ram heads that are restrained from revolving during compaction
  - the axis of the ram shall be perpendicular to the platen of the compactor
  - the ram shall apply and maintain a pressure of 600 ± 18 kPa perpendicular to the cylindrical axis of the specimen during compaction (see NOTE 1)
  - the compactor shall tilt 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 shall be designed to permit the specimen mold to revolve freely on its tilted axis during gyration.

NOTE 1: This stress calculates to 10600 ± 310 N total force for 150 mm (5.912 in.) specimens.

- ♦ specimen height measurement and recording device:
  - When specimen density is to be monitored during compaction, a means shall be provided 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 shall have steel walls that are at least 7.5 mm (0.3 in.) thick and are hardened to at least Rockwell C48.
  - The inside finish of the molds shall have a root mean square (rms) of 1.60 µm or smoother (see NOTE 2).
  - Molds shall 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.

NOTE 2: 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 shall be fabricated from steel with a minimum Rockwell hardness of C 48.

  - The ram heads shall stay perpendicular to its axis.
  - The platen side of each mold bottom shall be flat and parallel to its face.
  - All ram and base plate faces (the sides presented to the specimen) shall be ground flat to meet smoothness requirement according to ANSI B 46.1 and shall have a diameter of 149.50 to 149.75 mm (5.885 to 5.896 in.).

- mercury thermometer capable of measuring the temperature specified in the test procedure and marked in 1 °C (2 °F) divisions
- a 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
- flat bottom metal pans
- scoop, spatula, trowel
- large mixing spoon
- containers
- beakers
- grill type tins
- paper disks
- gloves
- mechanical mixer (optional)
- lubricating materials.

NOTE 3: 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 the ram pressure, the angle of gyration, the gyration frequency, the 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.

Verification of calibration system standardization and quality checks may be performed by the manufacturer, other agencies providing such services or in-house personnel. Frequency of verification shall follow manufacturer's recommendations.

Section 4
Preparations

Preparing Apparatus

Use the following procedure to prepare the apparatus.

Preparing Apparatus	
Step	**Action**
1	Warm up the compactor prior to 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 four rollers.
5	When monitoring the specimen height, the following preparation is required: ♦ Prior to the time of placing the paving mix in the mold, turn on the device for measuring and recording the height of the specimen and verify the readout is in the proper units, mm, and that 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

Use the following procedure 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 the specimens are to be used 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 maximum number of gyrations. NOTE 4: 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 the dry heated aggregate until all sizes are blended thoroughly. ♦ 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. ♦ Mechanical mixing shall be used.
6	Place the loose mix in a shallow flat pan after completing the mixture preparation, and spread to an

Preparing Sample	
Step	**Action**
	even thickness.
7	Place the shallow flat pan with the loose mix in an oven at the compaction temperature selected from Step 3 for two hours (short-term aging period). NOTE 5: Two-hour short-term aging period is used for volumetric design.
8	Place a compaction mold base plate and top plate in an oven at the selected compaction temperature from Step 3, 30 to 60 minutes prior to compaction.
9	If loose HMA plant mix is used, the mixture shall be brought to the compaction temperature range by careful uniform heating in an oven immediately prior to molding.

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
76-22	325	300

Section 5
Procedures

Compaction

Use the following procedure for compacting the mixture.

Compaction	
Step	**Action**
1	Select the desired number of gyrations for compaction according to 'Compaction Parameters.'
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. Care should be taken to avoid segregation in the mold. ♦ After all the mix is in the mold, level the mix 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 kPa ± 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 6: Specimen can be extruded from the mold immediately for most HMA paving mixes. For lean, rich or tender mixtures, a cooling period of 5 to 10 minutes in front of a fan may be necessary before extruding the specimen.
9	Remove the paper disks from the top and bottom of the specimens. NOTE 7: Before reusing the mold, place it in the oven for at least 5 minutes. The use of multiple molds will speed up the compaction process.

Density

When the specimen height is to be monitored, the following steps are required in addition to those specified in 'Preparing Sample.'

Density	
Step	**Action**
1	Determine the maximum specific gravity (G_r) of the loose mix according to Test Method "Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures" using a companion sample. The companion sample shall be aged 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.
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 Test Method "Tex-207-F, Determining Density of Compacted Bituminous Mixtures."

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

Compaction Parameters				
Design ESALs[1] (million)	**Compaction Parameters**			**Typical Roadway Application[2]**
	$N_{initial}$	**N_{design}**	**$N_{maximum}$**	
< 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 would be considered 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 two-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 interstate.
≥ 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 two-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-year period. Regardless of the actual design life of the roadway, determine the design ESALs for 20 years, and choose the appropriate N_{design} level.
2. Typical Roadway Applications as defined by A Policy on Geometric Design of Highway and Streets, 1994, AASHTO.

Section 6
Calculations

Calculate the uncorrected relative density (C_{ux}) at any point in the compaction process using the following equation:

$$\% G_{mmux} = \frac{A}{V_{mx} \; G_r \; G_m} \text{ x } 100$$

Where:

- $\%G_{mmux}$ = Uncorrected relative density at any point during compaction expressed as a percent of the theoretical maximum specific gravity
- A = The mass of the specimen in grams
- G_r = Theoretical maximum specific gravity of the mix
- G_m = The unit weight of water, 1g/cm^3
- x = The number of gyrations
- V_{mx} = The 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:

$$V_{mx} = \frac{\pi^2 \; h_x}{4 \text{ x } 1000}$$

NOTE 12: 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 (Cx) at any point in the compaction process as follows:

$$\% G_{mmx} = \frac{G_a \; h_{mm}}{G_r \; h_x} \text{ x } 100$$

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.