Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor AASHTO T 312-22

3. SIGNIFICANCE AND USE

3.1. This standard is used to prepare specimens for determining the mechanical and volumetric properties of asphalt mixtures. 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.

3.2 This test method may be used to monitor the density of test specimens during their preparation. It may also be used for field control of an asphalt mixture production process.

4. APPARATUS

4.1. *Superpave Gyratory Compactor* – An electrohydraulic or electromechanical compactor with a ram and ram heads as described in Section 4.3.....

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 (Note 1) .....

The compactor shall tilt the specimen molds at an average internal angle of 20.2 ± 0.35 mrad (1.16 ± 0.02 degrees), determined in accordance with T 344.....

The compactor shall gyrate the specimen molds at a rate of 30.0 ± 0.5 gyrations per minute throughout compaction.....

Note 1 – This stress calculates to 10 600 ± 310 N total force for 150 mm specimens.....

4.1.1. *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.....

4.1.2. The system may include a connected printer 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.....

4.1.3. The loading system, ram, and pressure indicator shall be capable of providing and measuring a constant vertical pressure of 600 ± 60 kPa during the first five gyrations, and 600 ± 18 kPa during the remainder of the compaction period.....

4.2. *Specimen Molds* – Specimen molds shall have steel walls that are at least 7.5 mm thick.....

And are hardened to at least a Rockwell hardness of C48.....

The initial inside finish of the molds shall have a root mean square (rms) of 1.60 µm or smoother when measured in accordance with ASME B46.1 (see Note 2) .....

New molds shall be manufactured to have an inside diameter of 149.90 to 150.00 mm.....

The inside diameter of the in-service molds shall not exceed 150.2 mm.....

Molds shall be at least 250 mm in length.....

The inside diameter and length of the molds shall be measured in accordance with Annex A.....

Note 2 – One source of supply for a surface comparator, which is used to verify the rms value of 1.60 µm, is GAR Electroforming, Danbury Connecticut.....

4.3. *Ram Heads and End Plates* – Ram heads and end plates shall be fabricated from steel with a minimum Rockwell hardness of C48.....

The ram heads shall stay perpendicular to their axis.....

The platen side of each end plate shall be flat and parallel to its face.....

All ram and end plate faces (the sides presented to the specimen) shall be flat to meet the smoothness requirement in Section 4.2 and shall have a diameter of 149.50 to 149.75 mm.....

4.4. *Thermometers* – Thermometers for measuring temperature of aggregates, binder, and asphalt mixtures shall meet the requirements of M339M/M339 with a temperature range of at least 10 to 230°C, and an accuracy of ± 2.5°C (±4.5°F) (see Note 3) .....

Note 3 - Thermometer types suitable for use include ASTM E1 mercury thermometers; ASTM E230/E230M thermocouple thermometer, Type J, any Class, or Type K, Class 1 or 2; IEC 60584 thermocouple thermometer, Type J, any Class, or Type K, Class 1 or 2; ASTM E2877 digital metal stem thermometer; or dial gauge metal stem (bi-metal) thermometer.

4.5. *Balance* – A balance meeting the requirements of M231, Class G5, for determining the mass of aggregates, binder, and asphalt mixtures.....

4.6. *Oven* – An oven, thermostatically controlled to ± 3°C, for heating aggregates, binder, asphalt mixtures, and equipment as required.....

The oven shall be capable of maintaining the temperature required for mixture conditioning in accordance with R 30.....

4.7. *Miscellaneous* – Flat-bottom metal pans for heating aggregates, scoop for batching aggregates, containers (grill-type tins, beakers, containers for heating asphalt), large mixing spoon or small trowel, large spatula, gloves for handling hot equipment, paper disks, mechanical mixer (optional), lubricating materials recommended by compactor manufacturer.....

4.8. *Maintenance* – In addition to routine maintenance recommended by the manufacturer, check the Superpave gyratory compactor's mechanical components for wear, and perform repair, as recommended by the manufacturer.....

6. STANDARDIZATION

6.1. Items requiring periodic verification of calibration include the 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.....

Verification of calibration, systems standardization, and quality checks may be performed by the manufacturer, other agencies proving such services, or in-house personnel.....

Frequency of verification shall follow the manufacturer's recommendations.....

6.2. The angle of gyration refers to the internal angle (tilt of the mold with respect to the end plate surface within the gyratory mold).....

The calibration of the internal angle of gyration shall be verified in accordance with T 344.....

7. PREPARATION OF APPARATUS

7.1. Immediately prior to the time when the asphalt mixture is ready for placement in the mold, turn on the main power for the compactor for the manufacturer's required warm-up period.....

7.2. Verify the machine settings are correct for angle, pressure, and number of gyrations.....

7.3. Lubricate any bearing surfaces as needed per the manufacturer's instructions.....

7.4. When specimen height is to be monitored, the following additional item of preparation is required. Immediately prior to the time when the asphalt mixture is ready for placement 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 recording device is ready.....

Prepare the computer, if used, to record the height data, and enter the header information for the specimen.....

8. ASPHALT MIXTURE PREPARATION

8.1. Laboratory Prepared:

8.1.1. Weigh the appropriate aggregate fractions into a separate pan, and combine them 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 mix analysis and performance specimens, batch weights will be adjusted to create a given density in a known volume.....

If the specimens are to be used for the determination of volumetric properties, the batch weights will be adjusted to result in a compacted specimen having dimensions of 150 mm in diameter and 115 $\pm$ 5 mm in height at the desired number of gyrations.....

Note 4 – It may be necessary to produce a trial specimen to achieve this height requirement. Generally, 4500 to 4700 g of aggregate are required to achieve this height for aggregates with combined bulk specific gravities of 2.550 to 2.700, respectively.....

8.1.2. Place the aggregate and binder container in the oven and heat them to the required mixing temperature.....

8.1.2.1. The mixing temperature range is defined as the range of temperature where the unaged binder has a viscosity of 0.17 $\pm$ 0.02 Pa·s when measure in accordance with T 316.....

Note 5 – Modified asphalts may not adhere to the equiviscosity requirements noted, and the manufacture's recommendations should be used to determine mixing and compaction temperatures.....

8.1.3. Charge the mixing bowl with the heated aggregate from one pan and dry-mix thoroughly...

Form a crater in the dry-blended aggregates, and weigh the required amount of binder into the mix

Immediately initiate mixing.....

8.1.4. Mix the aggregate and binder as quickly and thoroughly as possible to yield an asphalt mixture having a uniform distribution of binder. As an option, mechanical mixing may be used.....

8.1.5. After completing the mixture preparation, perform the required mixture conditioning in accordance with R 30.....

8.1.6. Place the compaction mold(s) in an oven at the required compaction temperature for a minimum of 30 min prior to the estimated beginning of compaction (during the time the mixture is being conditioned in accordance with R 30) .....

Place any additional compaction surfaces, such as base plates and upper plates, into the oven with and for the same time frame as the molds, according to the manufacturer's instructions.....

8.1.7. Following the mixture conditioning period specified in R 30, if the mixture is at the compaction temperature, proceed immediately with the compaction procedure as outlined in Section 9.....

If the compaction temperature is different from the mixture conditioning temperature used in accordance with R 30, place the mix in another oven at the compaction temperature for a brief time (maximum of 30 min) to achieve the required temperature.....

8.1.7.1. The compaction temperature is the midpoint of the range of temperatures where the unaged binder has a viscosity of 0.28 ± 0.03 Pa·s when measured in accordance with T 316 (see Note 5.)..

8.2. Plant Produced

8.2.1. Place the compaction mold(s) in an oven at the required compaction temperature (see Section 8.1.7.1.).....

Place any additional compaction surfaces, such as base plates and upper plates, into the oven with and for the same time frame as the molds, according to the manufacturer's instructions.....

8.2.2. Obtain the sample in accordance with R 97.....

8.2.3. Reduce the sample in accordance with R 47.....

8.2.4. Place the sample into a pan to a uniform thickness.....

8.2.5. Bring the asphalt mixture to the compaction temperature range by careful, uniform heating in an oven immediately prior to molding.....

9. COMPACTION PROCEDURE

9.1. When the compaction temperature is achieved, remove the heated mold and any compaction surfaces from Section 8.1.6 or 8.2.1 from the oven.....

Place the base plate and a paper disk in the bottom of the mold.....

9.2. Place the mixture into the mold in 1 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 on top of the levelled material.....

Complete any remaining mold assembly, load the mold into the compactor, and center the loading ram according to the manufacturer's instructions.....

9.3. Apply a pressure of 600 ± 18 kPa on the specimen.....

9.4. Apply a 20.2 ± 0.35 mrad (1.16 ± 0.02 degrees) average internal angle to the mold assembly and begin the gyratory compaction.....

9.5. Allow the compaction to proceed until the desired number of gyrations specified in R 35 is reached and gyratory mechanism shuts off.....

9.6. Remove the angle from the mold assembly, remove the ram pressure, and retract the loading ram in the order specified by the SGC manufacturer (the preceding steps may be done automatically by the compactor on some models of SGCs) .....

Remove the mold from the compactor (if required), and extrude the specimen from the mold.....

Note 6 – No additional gyrations with the angle removed are required unless specifically called for in another standard referencing T 312. The extruded specimen may not be a right angle cylinder. Specimen ends may need to be sawed to conform to the requirements of specific performance tests.....

Note 7 – The specimens can be extruded from the mold immediately after compaction for most asphalt mixtures. However, a cooling period of 5 to 10 min in front of a fan may be necessary before extruding some specimens to ensure the specimens are not damaged.....

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

Note 8 – Before reusing the mold, place it in an oven for at least 5 min. The use of multiple molds will speed up the compaction process.....

10. DENSITY PROCEDURE

10.1. Determine the maximum specific gravity (G_{mm}) of the loose mix in accordance with T 209 using a companion sample.....

The companion sample shall be conditioned to the same extent as the compaction sample.....

10.2. Determine the bulk specific gravity (G_{mb}) of the specimen in accordance with T 166 or T 275 as appropriate.....

10.3. When the specimen height is to be monitored, record the specimen height to the nearest 0.1 mm after each revolution.....

11. DENSITY CALCULATONS

11.1. Calculate the uncorrected relative density ($\%G_{mmux}$) at any point in the compaction process using the following equation: .....

$$\%G_{mmux} = \frac{W_m}{V_{mx}G_{mm}G_m} \times 100$$

Where:

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

W_m = mass of the specimen, g

G_{mm} = theoretical maximum specific gravity of the mix

G_m = unit weight of water, 1 g/cm^3

χ = number of gyrations

V_{mx} = volume of the specimen, in cm^3, at any point based on the diameter (d) and height (h_x) of the specimen at that point (use "mm" for height and diameter measurements)

It can be expressed as:

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

Note 9 – This formula gives the volume in cm^3 to all for a direct comparison with the specific gravity

11.2. At the completion of the bulk specific gravity test (G_{mb}), determine the relative density ($\%G_{mmx}$) at any point in the compaction process as follows: .....

Where:

$$\%G_{mmx} = \frac{G_{mb} h_m}{G_{mm} h_x} \times 100$$

Where:

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

G_{mb} = bulk specific gravity of the extruded specimen

h_m = height in millimetres of the extruded specimen

h_x = height in millimetres of the specimen after χ gyrations

12. REPORT

Report the following information in the compaction report, if applicable:

12.1. Project name;

12.1.2. Date of the test;

12.1.3. Start time of the test;

12.1.4. Specimen identification;

12.1.5. Percent binder in specimen, nearest 0.1 percent;

12.1.6. Average diameter of the mold used *(d),* nearest 1.0 mm;

12.1.7. Mass of the specimen (W_m), nearest 0.1 g;

12.1.8. Maximum specific gravity (G_{mm}) of the specimen by T 209, nearest 0.001;

12.1.9. Bulk specific gravity *(G_{mb})* of the specimen by T 166 or T 275, nearest 0.001;

12.1.10. Height of the specimen after each gyration *(h_x),* nearest 0.1 mm;

12.1.11. Relative density *($\%G_{mm}$)* expressed as a percent of the theoretical maximum specific gravity *(G_{mm}),* nearest 0.1 percent; and

12.1.12. Gyration angle, nearest 0.2 mrad (0.01 degrees), and the method used to determine or verify the gyration angle.

13. PRECISION AND BIAS

13.1.1. *Precision:*

13.2. *Single-Operator Precision* – The single operator standard deviations (1s limits) for relative densities at N_{ini} and N_{des} for mixtures containing aggregate with an absorption of less than 1.5 percent are shown in Table 1. The results of two properly conducted tests on the same material, by the same operator, using the same equipment, should be considered suspect if they differ by more than the d2s single operator limits shown in Table 1.

13.3. *Multi-Laboratory Precision* – The multi-laboratory standard deviations (1s limits) for relative densities at N_{ini} and N_{des} for mixtures containing aggregate with an absorption of less than 1.5 percent are shown in Table 1. The results of two properly conducted tests on the same material, by different operators, using different equipment, should be considered suspect if they differ by more than the d2s multi-laboratory limits shown in Table 1.

Table 1-Precision Estimates[a]

	1s limit Relative Density, %	d2s limit Relative Density, %
Single-operator precision:		
12.5-mm nominal max agg.	0.3	0.9
19.0-mm nominal max agg.	0.5	1.4
Multi-laboratory precision:		
12.5-mm nominal max agg.	0.6	1.7
19.0-mm nominal max agg.	0.6	1.7

a Based on an interlaboratory study described in NCHRP Research Report 9-26 involving 150-mm diameter specimens with 4 to 5 percent air voids, 26 laboratories, two materials (a 12.5-mm mixture and a 19.0-mm mixture), and three replicates. Specimens were prepared in accordance with T 312-04. The angle of gyration was verified using Method A, external angle.

13.4. *Bias – No* information can be presented on the bias of the procedure because no material having an accepted reference value is available.

ANNEX A – EVALUATING SUPERPAVE GYRATORY COMPACTOR (SGC) MOLDS – MANDATORY

A1. SCOPE

A1.1. This Annex (A1 through A7) covers the evaluation of the molds as a check for compliance with the requirements outlined in Sections 4.2. and 4.3. Measurements of the mold inside diameter and end-plate diameters as well as visual inspection of critical surface conditions are included.....

Minimum frequency of this evaluation is 12 months or 80 hours of operation.....

The inside diameter of the molds may be measured using a three-point bore gauge or a Coordinate Measuring Machine (CMM). See Annexes A4 and A5 for additional procedures for using these devices.....

Note A1-Because CMMs are typically limited to manufacturers, it is considered best practice for a lab to also use the three-point bore method as a check before putting a mold into service.