Designation: D 6925 – 03

Standard Test Method for Preparation and Determination of the Relative Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor[1]

This standard is issued under the fixed designation D 6925; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This standard concerns the compaction of cylindrical specimens of hot mix asphalt (HMA) using the Superpave Gyratory Compactor (SGC). This standard also refers to the determination of the relative density of the compacted specimens at any point in the compaction process. Compacted specimens are suitable for volumetric and physical property testing.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 1188 Test Method for Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Coated Samples

D 2041 Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures

D 2726 Test Method for Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens

D 4402 Test Method for Viscosity Determination of Asphalt at Elevated Temperatures Using a Rotational Viscometer

D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Testing Soil, Rock, and Related Construction Materials

2.2 *AASHTO Standards:*

PP35 Provisional Practice for Evaluation of Superpave Gyratory Compactors (SGCs)[3]

AASHTO T312 Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by means of the Superpave Gyratory Compactor[3]

2.3 *Other References:*

ANSI B46.1 American National Standards Institute

PP ## Standard Practice for Evaluation of Superpave Gyratory Compactor (SGC) Internal Angle of Gyration

Asphalt Institute MS-2 Mix Design Methods for Asphalt Concrete

Ruggedness Evaluation of AASHTO TP4 The Superpave Gyratory Compactor, McGennis, R; Kennedy, TW; Anderson, VL; Perdomo, D, Journal of the Association of Asphalt Paving Technologists Vol: 66

3. Significance and Use

3.1 This standard is used to prepare specimens for determining the volumetric and physical properties of HMA specimens.

3.2 This test method is useful for monitoring the density of test specimens during the compaction process. This method is suited for the laboratory design and field control of HMA.

4. Apparatus

4.1 *Superpave Gyratory Compactor*—An electromechanical, electro hydraulic, or electro pneumatic compactor comprised of the following system components: *(1)* reaction frame, and drive motor, *(2)* loading system, loading ram, and pressure indicator, *(3)* height measurement and recording system, and *(4)* mold and base plate.

4.1.1 The reaction frame shall provide a non-compliant structure against which the vertical loading ram can push when compacting specimens. Reaction bearings shall be capable of creating, and firmly maintaining during the compaction process, an external angle of gyration of 21.8 ± 0.4 mrad (1.25 ± 0.02 degrees).

NOTE 1—Research has shown external angle (measurement between the external mold wall and the frame of the compactor) to be different

[1] This test method is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.20 on Mechanical Tests of Bituminous Mixtures.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001.

from the internal angle (measurement between internal mold wall and top and bottom plate). The difference between these measurements varies for different types of compactors. Some discrepancies in relative density have been resolved by use of the internal angle adjustment. Agencies may choose the internal angle as the basis for calibration. If internal angle is chosen for calibration the recommendation of the Superpave expert task group is to use an internal angle of 20.2 ± 0.4 mrad (1.16 ± 0.02 degrees). (See AASHTO PP ## for the procedure to determine the internal angle).

4.1.2 The rotating base and drive motor shall be capable of gyrating the specimen at a rate of 30.0 ± 0.5 revolutions per minute. The compactor shall be designed to permit the specimen mold to gyrate freely on its tilted axis during compaction.

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 process.

NOTE 2—The report on the ruggedness evaluation of AASHTO TP4, "Standard Method for Preparing and Determining the Density of Hot Mix Asphalt Specimens by Means of the SHRP Gyratory Compactor," (McGennis, et.al 1997) indicated that the pressure tolerance of ±18 kPa resulted in significantly different values of bulk specific gravity of the compacted specimens (G_{mb}) in some cases. However, since the pressure is directly set at 600 kPa, the tolerance of ±18 kPa should apply only to the ability of the SGC to maintain vertical pressure during compaction. To minimize potential errors caused by pressure, operators should take care during calibration verification to assure that the specified pressure has been attained.

4.1.4 The axis of the loading ram shall be perpendicular to the platen of the compactor.

4.1.5 The height measurement and recording system shall be capable of continuously measuring and recording the height of the specimen during the compaction process to the nearest 0.1 mm. The height shall be recorded once per gyration.

4.1.6 The system shall record test information, such as specimen heights per gyration. This may be accomplished through data acquisition or printing.

4.2 *Specimen Molds*—Specimen molds shall have steel walls that are at least 7.5 mm thick and are hardened to Rockwell C48 or better. Molds shall have an inside diameter of 149.90 mm to 150.00 mm and be at least 250 mm high. The inside finish of the molds shall be smooth (rms of 1.60 mm or smoother when measured in accordance with ANSI B46.1).

4.3 *Mold Plates and Ram Heads*—All mold plates and ram heads shall be fabricated from steel with a minimum Rockwell hardness of C48. The mold plates and ram heads shall be flat. Mold plates and ram heads (if in contact with the HMA specimen) shall have an outside diameter of 149.50 mm to 149.75 mm.

4.4 *Thermometers*—Armored, glass, or dial type thermometers with metal stems for determining the temperature of aggregates, asphalt binders, and asphalt mixtures between 10°C and 232°C, with a minimum sensitivity of 3°C.

4.5 *Balance*—The balance shall have a minimum capacity of 10 000 g with a sensitivity of 0.1 g. The balance shall conform to Specification D 4753 as a Class GP2 balance.

4.6 *Ovens*—Two ovens are recommended. One oven shall be a forced draft oven capable of maintaining the temperature required, nominally 135°C, for short term aging as described in 6.5. At least one more oven shall be available for heating aggregates, asphalt binders, and equipment. This oven shall have a range to a minimum of 204°C, thermostatically controlled to ± 3°C.

4.7 *Miscellaneous*—Miscellaneous equipment may include: flat bottom metal pans for heating aggregates; scoops for batching aggregates; containers for heating asphalt binders; mixing spoons; trowels; spatulas; welders gloves for handling hot equipment; 150 mm paper disks; lubricants for moving parts; laboratory timers; and mechanical mixers.

5. Standardization

5.1 Items requiring periodic verification of calibration include the vertical pressure, angle of gyration, frequency of gyration, height measurement system, and oven temperature. Verification of the mold and platen dimensions and smoothness of finish is also required. Verification of calibration, system standardization, and quality checks shall be performed by the manufacturer, other agencies providing standardization services, or in-house personnel.

5.2 It is recommended that the user verify the calibration of the following items following the manufacturer's recommendations: angle, pressure, height, and rotational speed.

NOTE 3—If no manufacturer recommendations are available, the following schedule should be sufficient to assure the user that the SGC is operating using the proper parameters:

Angle of gyration	monthly
Vertical Pressure	monthly
Height Measurement System	monthly
Frequency of Gyration	quarterly
Mold and platen dimensions	annually

Calibration shall be performed if the gyratory compactor is transported to a new location.

NOTE 4—Unknown SGC equipment shall be evaluated using procedures described in AASHTO PP35 to assess its ability to produce compacted specimens at various compaction levels which are equivalent to two models of SGC (Pine and Troxler), which have been used by most of the state DOT's in the past, and are known to have met the specifications.

6. Preparation and Compaction of Test Specimens (Laboratory Design)

6.1 *Preparation of Aggregates*—Weigh and combine the appropriate aggregate fractions to the desired specimen weight. The specimen weight will vary based on the ultimate disposition of the test specimens. If a target air void level is desired, specimen weights will be adjusted to create a given density in a known volume. If the specimens are to be used for determination of volumetric properties, the weights will be adjusted to result in a compacted specimen having dimensions of 150 mm in diameter and 115 ± 5 mm in height at the required number of gyrations.

NOTE 5—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 2.55 to 2.70 respectively.

NOTE 6—Details of aggregate preparation may be found in any suitable mix design manual, such as the Asphalt Institute's MS-2, Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types.

NOTE 7—The required number of gyrations for purposes of determining volumetric properties of an asphalt mixture specimen is based primarily on design traffic. Table 1 shows recommended number of gyrations for design traffic levels.

6.2 Place the blended aggregate specimens and asphalt binder in an oven and bring to the required mixing temperature. Heat the mixing container and all necessary mixing implements to the required temperature.

6.2.1 The laboratory mixing temperature range is typically defined as the range of temperatures where the unaged asphalt binder has a kinematic viscosity of 170 ± 20 mm^2/s (approximately 0.17 ± 0.02 Pa-s for an asphalt binder density of 1.000 g/cm^3) measured in accordance with Test Method D 4402.

NOTE 8—Modified asphalt binders, especially those produced with polymer additives, generally do not adhere to the equi-viscous ranges noted in 6.2.1 and 6.6.1. The user should refer to the asphalt binder manufacturer to establish appropriate mixing and compaction temperature ranges. In no case should the mixing temperature exceed 175°C.

6.3 Charge the heated mixing bowl with the dry, heated aggregate and dry mix. Form a crater in the heated aggregate blend and weigh the required amount of asphalt binder into the aggregate blend. Immediately initiate mixing.

6.4 Mix the asphalt binder and aggregate as quickly and thoroughly as possible to yield an asphalt mixture having a uniform distribution of asphalt binder. Because of the large batch weights, a mechanical mixer is preferable for the mixing process.

6.5 After completing the mixing process, subject the loose mix to short-term conditioning for 2 h ± 5 min at the compaction temperature ± 3°C. Stir the mix after 60 ± 5 min to maintain uniform conditioning.

6.6 Place a compaction mold assembly in an oven at the required compaction temperature ± 5°C for a minimum of 45 min prior to the compaction of the first mixture specimen (during the time the mixture is in the conditioning process described in 6.5).

6.6.1 The compaction temperature range is defined as the range of temperatures where the unaged asphalt binder has a kinematic viscosity of 280 ± 30 mm^2/s (approximately 0.28 ± 0.03 Pa-s for an asphalt binder density of 1.000 g/cm^3) measured in accordance with Test Method D 4402. See also Note 8.

6.7 Verify the settings on the compactor. Unless noted otherwise, the SGC should be initialized to provide specimen compaction using the settings described in 4.1.

6.8 At the end of the conditioning period, remove the loose mix sample and the compaction mold assembly from the oven. Place a paper disk inside the mold to aid separation of the specimen from the base plate after compaction.

TABLE 1 Superpave Design Gyratory Compactive Effort

Design ESALs, (Millions)	Compaction Parameters		
	N_{ini}	N_{des}	N_{max}
< 0.3	6	50	75
0.3 to< 3	7	75	115
3 to< 30	8	100	160
^{3} 30	9	125	205

NOTE—ESALs are based on 20 year design life regardless of actual design life.

6.9 Quickly place the mixture into the mold using a transfer bowl or other suitable device. Take care to minimize segregation of the mixture in the mold. After the mixture has been completely loaded into the mold place a paper disk on the mixture to avoid material adhering to the ram head or top mold plate. If necessary, place the top mold plate on top of the paper disk.

6.10 Load the compaction mold into the SGC and initiate the compaction process. In most SGCs, this is an automatic process consisting of pressing a key to start the compaction process. The compactor will apply a vertical pressure, induce the angle, and begin compaction. Compaction shall proceed to the desired endpoint—either a required number of gyrations (for determination of volumetric properties), or a specified height (for use in physical property testing).

6.11 At the end of the compaction process, remove the mold assembly from the SGC. After a suitable cooling period, extrude the compacted specimen from the mold, and remove the paper disks.

NOTE 9—The purpose of the cooling period is to ensure that the specimen will not deform when it is extruded. Cooling may be facilitated using a fan. For some specimens with high air voids (7 % or more) that will be used in physical property testing, this period may be as long as 15 min or more. Operator experience should dictate the length (and necessity) of the cooling period to avoid deformation of the compacted mixture specimen. Under no circumstances should specimens which have bulged or otherwise deformed be used for any testing purposes.

6.12 Place the extruded specimen on a flat surface in an area where it can cool, undisturbed, to room temperature. Place the compaction mold assembly back in the oven for a minimum of 20 min before reusing.

6.13 Collect the printout or save the data to file of the height measurements for each gyration.

7. Preparation and Compaction of Test Specimens (Field Plant Mix Samples)

7.1 For samples of as-produced mixture, follow the process in 6.6 to 6.13.

8. Densification Procedure

8.1 When the specimen densification is to be monitored, as in a volumetric mix design, the following steps are required in addition to those specified in Section 6.

8.1.1 Record the specimen height to the nearest 0.1 mm after each gyration.

8.1.2 Determine the mass of the extruded specimen to the nearest 0.1 g. Determine the bulk specific gravity of the extruded specimen in accordance with Test Method D 1188 or Test Method D 2726.

8.1.3 Determine the maximum theoretical specific gravity of the loose mixture in accordance with Test Method D 2041, using a companion sample. The companion sample shall be conditioned to the same extent as the compacted specimen using AASHTO PP2.

9. Densification Calculations

9.1 At the completion of either Test Method D 1188 or Test Method D 2726, and Test Method D 2041, determine the corrected relative density (C_n) as follows:

$$C_n = \frac{G_{mb} \cdot h_m}{G_{mm} \cdot h_n} \cdot 100 \quad (1)$$

where:

C_n = corrected relative density at any gyration, n, during the compaction process, expressed as a percentage of the maximum theoretical specific gravity,
G_{mb} = bulk specific gravity of the extruded specimen,
G_{mm} = maximum theoretical specific gravity of the mixture (companion sample),
h_m = height of the specimen recorded at the final gyration, mm, and
h_n = height of the specimen recorded at any gyration, n, during the compaction process, mm.

NOTE 10—The corrected relative density calculated at any gyration (n) using the above equation is an approximation based of back calculation. Due to inherent variability in aggregates as well as blending and mixing of HMA specimens, the actual relative density of an alternate specimen produced using the same materials at any given number of gyrations (n) may not exactly correlate with the relative density calculated using the above equation.

10. Report

10.1 Report the following information:

10.1.1 Project details,

10.1.2 Date and time of specimen preparation,

10.1.3 Specimen identification,

10.1.4 Percentage of asphalt binder in specimen, to the nearest 0.1 percent,

10.1.5 Mass of the specimen, to the nearest 0.1 g,

10.1.6 Maximum theoretical specific gravity (G_{mm}) of the companion specimen by Test Method D 2041, to the nearest 0.001,

10.1.7 Bulk specific gravity of the compacted specimen (G_{mb}) by Test Method D 1188 or Test Method D 2726, to the nearest 0.001,

10.1.8 Height of the compacted specimen after each gyration (h_n), to the nearest 0.1 mm, and

10.1.9 Corrected relative density (C_n), expressed as a percentage of the maximum theoretical specific gravity, to the nearest 0.1 % at selected number of gyrations which cover the range of N_{des} or N_{max}.

TABLE 2 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
Multilaboratory 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 4-5 percent air voids, twenty-six laboratories, two materials (a 12.5-mm mixture and a 19.0-mm mixture), and three replicates.

11. Precision and Bias

11.1 *Precision*:

11.1.1 *Single Operator Precision*—The single operator standard deviations (1s limits) for densities at N_{ini} and N_{des}, for mixtures containing aggregate with an absorption of less than 1.5 percent, are shown in Table 2. 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 2.

11.1.2 *Multilaboratory Precision*—The multilaboratory 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 2. 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 mulilaboratory limits shown in Table 2.

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

12. Keywords

12.1 asphalt; compaction; density; gyratory; superpave