Designation: D7115 – 10 (Reapproved 2015)

Standard Test Method for Measurement of Superpave Gyratory Compactor (SGC) Internal Angle of Gyration Using Simulated Loading[1]

This standard is issued under the fixed designation D7115; 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 test method covers the procedure for the measurement of the Superpave Gyratory Compactor (SGC) internal angle of gyration using an instrument capable of simulating loading conditions similar to those created by a hot mix asphalt specimen.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.2.1 IEEE/ASTM SI 10, American National Standard for the Use of International System of Units (SI): The Modern Metric System, offers guidance where use of decimal degrees for plane angles (versus radians) and revolutions per minute for rate of gyration (versus radians per second) is acceptable within the IEEE/ASTM SI 10 system when used on a minimal basis.

1.3 The text of this test method references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard

1.4 *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]

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

D2726 Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures

D3666 Specification for Minimum Requirements for Agencies Testing and Inspecting Road and Paving Materials

D6752 Test Method for Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Automatic Vacuum Sealing Method

D6925 Test Method for Preparation and Determination of the Relative Density of Asphalt Mix Specimens by Means of the Superpave Gyratory Compactor

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

IEEE/ASTM SI 10 American National Standard for the Use of International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions:*

3.1.1 *external angle*—the angle formed between the external mold diameter and a stationary reference axis of the machine frame.

3.1.2 *internal angle*—the angle formed between the internal mold diameter and a mold end plate as a mold is gyrated in an SGC.

3.1.3 *top internal angle*—the angle formed between the internal mold diameter and the upper mold end plate as a mold is gyrated in an SGC.

3.1.4 *bottom internal angle*—the angle formed between the internal mold diameter and the lower mold end plate as a mold is gyrated in an SGC.

3.1.5 *effective internal angle*—the average of the top internal angle and the bottom internal angle.

3.1.6 *tilting moment*—a force (F) acting at one end of an SGC mold platen in a direction parallel to the axis of gyration, but acting at some distance (e) away from that axis. The tilting moment at one end of the mold platen is computed as the product of this distance (e) and force (F).

3.1.7 *total moment*—the sum total (M) of the tilting moment acting at the top of the mold and the tilting moment acting at the bottom of the mold.

3.1.8 *eccentricity*—the distance (e) away from the axis of gyration at which a force (F) is acting at one end of an SGC

[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 Asphalt 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.

mold. This use of the term eccentricity is consistent with previous published reports describing the mechanics of gyratory compaction.[3]

3.1.9 *standard SGC volumetric specimen*—a standard sized hot mix asphalt specimen prepared using an SGC for purposes of volumetric mix design. Such a standard specimen, prepared in accordance with Test Method D6925, has a diameter of 150 mm and a final compacted height of 115 ± 5 mm.

4. Summary of Test Method

4.1 The internal angle of gyration of an SGC is measured dynamically with an instrument inserted into the SGC mold.

4.2 A load (moment) is induced on the SGC while the internal angle is simultaneously measured. The simulated loading conditions are similar to those created by compaction of a standard SGC volumetric specimen.

4.3 The internal angles at each end of the mold are measured and then averaged to obtain the effective internal angle of gyration.

5. Significance and Use

5.1 SGCs are used to produce hot-mix asphalt (HMA) specimens in the laboratory to assess volumetric properties and predict pavement performance. In the fabrication of an SGC specimen in accordance with Test Method D6925, loose HMA is placed inside a metal mold, which is then placed into an SGC. A constant consolidation pressure is applied to the sample while the mold gyrates at a nominally constant angle (referred to as the angle of gyration) and rate. Consistency in the density of the asphalt specimens produced as measured by Test Methods D2726 or D6752 is very important to the validity of the tests performed. Specimens of a consistent density are produced when an SGC maintains a constant pressure and a known constant angle of gyration during the compaction process.

5.2 There are several manufacturers and models of SGC. Each model employs a unique method of setting, inducing, and maintaining the angle of gyration. Each model also employs a unique calibration system to measure the external angle of gyration. These existing calibration systems can not be used universally on all of the different SGC models commercially available. Inconsistencies in asphalt specimens produced on different SGC models have been at least partially attributed to variations in the angle of gyration.

5.3 This method describes instruments and processes that can be used to independently measure the internal angle of gyration of any manufacturers' SGC model under simulated loading conditions. The external shape of the instrument chassis assures that the points of physical contact between the mold end plates and the instrument occur at a fixed and known distance away from the axis of gyration. As a result, the vertical load is applied at these fixed points, creating tilting moments at each end of the mold.

5.4 Unless otherwise specified, a tilting moment of 466.5 N-m shall be applied to the SGC by the instrument while making this measurement.

NOTE 1—The quality of the results produced by this test method are dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of Practice D3666 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this test method are cautioned that compliance with Practice D3666 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of Practice D3666 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.

NOTE 2—A 466.5 N-m tilting moment corresponds to a 22 mm eccentric on the AFLS1 or a 21 deg cone angle on the DAVII-HMS with an applied load of 10603 N (600 kPa at a 150 mm diameter specimen setting).

6. Interferences

6.1 Debris on the SGC mold, base plates, ram head, reaction surfaces, or instrument can cause errant measurement results. Extreme care should be taken to thoroughly clean the SGC, mold, instrument, and any work areas that will be utilized during the measurement procedure.

6.2 Scarring or irregular surfaces on mold walls and end plates is also known to cause incorrect results. Do not use any equipment that shows signs of damage. The precision required in the execution of this test method necessitates that extreme care must be taken to avoid errors from damaged or improperly maintained equipment.

7. Apparatus

7.1 An instrument capable of being gyrated inside an SGC mold which induces tilting moments at each end of the SGC mold while simultaneously measuring an internal angle of gyration.

7.1.1 *Data Acquisition*—The timing of the data acquisition system may be automatically triggered by the start of the gyration process. Provision for excluding a known number of initial gyrations from the angle measurement may be provided (initial delay period), and the angle shall be measured throughout a known number of subsequent gyrations (data acquisition period). The durations of the initial delay and the data acquisition periods may be programmable or fixed.

7.1.2 *Display Options*—The angle measurement result(s) may be viewable on a display built into the instrument chassis or retrievable from the instrument by means of a communications port, or both.

7.1.3 *Temperature Measurement*—The instrument may optionally have a means for displaying, recording, or otherwise indicating its internal temperature during the angle measurement process.

7.1.4 *Static Angle Gage*—A National Institute of Standards and Technology (NIST)-traceable angle gage device with one or more known angles used to calibrate and to verify the calibration of the angle measurement instrument.

[3] Guler, M., Bahia, H. U., Bosscher, P. J., and Plesha, M. E., "Device for Measuring Shear Resistance of Hot Mix Asphalt in Gyratory Compactor," *Transportation Research Record 1723*, TRB, National Academy of Sciences, Washington, DC, 2000, pp. 116–124.

7.1.5 *Wear Protection Plates*—Thin steel plates (optional) which protect the SGC mold end plates from any cosmetic damage by the contact rings.

7.2 *Superpave Gyratory Compactor (SGC)* and associated equipment as described in Test Method D6925. The SGC shall be in good repair with the compaction pressure, specimen height measurement system, and gyration rate verified to be within specifications. The mechanisms used to induce and maintain the angle of gyration shall be set and maintained within the manufacturer's guidelines.

7.2.1 The SGC molds, mold end plates, base platens, and ram head surface smoothness shall be confirmed to be within the specifications of Test Method D6925. Any equipment not meeting these requirements shall not be used.

8. Preparation of Apparatus

8.1 Before each use of the angle measurement instrument, verify the angle measurement system using the static angle gage according to manufacturer's instructions. The static angle gage, which can apply one or more known angles to the instrument, is used to confirm that the instrument is operating within calibration. The instrument and the static angle gage must be at the same, uniform, stable temperature for the verification to be accurate.

NOTE 3—These instruments typically have an operating temperature range of 20 to 40°C. Consult the manufacturer's instructions for specific temperature limitations during calibration, verification, and use within the SGC.

8.2 Be sure the probe tips and contact rings on the angle measurement instrument are free of debris.

8.3 Prepare a clean compaction mold assembly.

NOTE 4—Accumulation of HMA on mold surfaces, mold end plates, base platens, or ram head surfaces, or combination thereof, directly impacts the instrument's ability to accurately measure the angle of gyration. Use mineral spirits or another appropriate solvent to clean these surfaces.

8.4 Perform the angle measurement with the SGC mold at room temperature. Optionally, the measurement may be made with the mold at an elevated temperature. If the angle measurement is to be made at an elevated temperature, then place the SGC mold in an oven at the desired temperature ± 5°C for a minimum of 45 min prior to making the first angle measurement. Do not place the angle measurement instrument in the oven. Mold temperatures other than room temperature used during angle measurement shall be noted on the report.

NOTE 5—The SGC manufacturer may recommend measurement of the angle at an elevated temperature for those SGC models where the angle changes with mold temperature.

NOTE 6—These instruments typically have an operating temperature range of 20 to 40°C. After use in a hot mold, the angle measurement instrument can be cooled by using a fan to blow ambient air over the instrument or by placing it in front of an air conditioner. Elevating the instrument above the table surface so as to permit maximum airflow over the entire instrument will increase the rate of cooling. Do not cool the instrument below room temperature. Consult the manufacturer's instructions for specific temperature limitations during calibration, verification, and use within the SGC.

8.5 Verify the settings on the compactor. Unless noted otherwise, the SGC shall be initialized to provide specimen compaction using a consolidation pressure of 600 ± 18 kPa, and the gyration rate shall be 30 ± 0.5 rpm.

8.6 Set the number of gyrations on the SGC in accordance with the recommendations of the manufacturer of the angle measurement instrument. Typically, ten gyrations are sufficient to obtain an accurate angle measurement using simulated loading.

9. Calibration and Standardization

9.1 The angle measurement instrument requires periodic standardization. The system shall be standardized prior to initial use and at least once every 12 months thereafter. This annual standardization shall follow instrument manufacturer recommendations and include the following:

9.1.1 Standardization of the static angle gage with a NIST traceable measurement system, and

9.1.2 Standardization of the angle measurement instrument.

10. Procedure

10.1 The average internal angle is based on six individual angle measurements as follows:

10.1.1 The top internal angle is measured in triplicate.

10.1.2 The bottom internal angle is measured in triplicate.

10.2 Each of the six individual angle measurements is performed as follows:

10.2.1 Arm the angle measurement instrument for collecting data.

10.2.2 Place the angle measurement instrument inside the SGC mold. Orient the instrument probes or reference base as appropriate to measure the top or bottom angle.

NOTE 7—The operator may wish to use a specimen extruder to elevate the bottom mold plate to a position where insertion of the angle measurement instrument into the SGC mold is easier.

10.2.3 Place the SGC mold inside the SGC.

NOTE 8—For some SGCs, it may be more convenient to first place the mold in the SGC, and then place the angle measurement instrument in the mold.

10.2.4 Initiate the compaction process. For most SGCs, this is an automatic process consisting of pressing a button to start the compaction process. The SGC automatically applies the ram pressure, induces the angle, and gyrates the mold to the specified number of gyrations.

10.2.5 Remove the angle measurement instrument from the SGC mold.

NOTE 9—Use caution when removing the instrument, especially when using a power extruder. Take care that the instrument does not get caught or damaged during the extrusion process.

10.2.6 Record the angle result reported by the instrument to nearest 0.01°. Record which angle (top or bottom) and which triplicate (1 or 2 or 3) was measured.

11. Calculations

11.1 Calculate the average top internal angle as follows:

$$\text{average top internal angle} = \frac{(\text{top angle } 1 + \text{top angle } 2 + \text{top angle } 3)}{3} \qquad (1)$$

11.2 Calculate the average bottom internal angle as follows:

$$\text{average bottom internal angle} = \frac{(\text{bottom angle 1} + \text{bottom angle 2} + \text{bottom angle 3})}{3} \quad (2)$$

11.3 Calculate the effective internal angle as follows:

$$\text{effective internal angle} = \frac{(\text{average top internal angle} + \text{average bottom internal angle})}{2} \quad (3)$$

12. Report

12.1 The report shall contain the following information:

NOTE 10—A sample report is provided in Appendix X1.

12.1.1 SGC Information: Manufacturer, Model No., S/N, Owner, Location, Number of Gyrations, Consolidation Pressure, and Mold Temperature used during angle measurement process,

12.1.2 Angle Measurement Instrument Identification: Manufacturer, S/N, Date of Calibration, Due Date for next calibration, and eccentricity,

NOTE 11—Consult the instrument manufacturer's manual for determination of the applied tilting moment for the particular instrument used.

12.1.3 Results from each of the individual angle measurements: Express each angle measurement to the nearest 0.01°, with notations indicating top or bottom angle,

12.1.4 Effective internal angle, and

12.1.5 Name and dated signature of the technician performing the test.

13. Precision and Bias[4]

13.1 The precision is based on an Interlaboratory Study (ILS #151) that was conducted in 2007 using Practice E691 and Practice C670. ILS #151 involved 27 laboratories, which featured 5 Troxler (DAVII-HMS) and 6 Pine Instrument AFLS1 (RAM) internal angle instruments and the following SGC models: Troxler Electronics 4140, 4141, and 414x; Pine Instrument AFG1, AFG2, AFGB1, AFGC125X; IPC ServoPac; and Interlaken. Within the study the internal angle measurements ranged from 1.014 to 1.290°.

13.1.1 *Single-Instrument Precision*—The single operator standard deviation of a single test result has been found to be 0.011°. Therefore, results of two properly conducted measurements by the same operator with the same instrument in the same SGC should not differ by more than 0.03°.

13.1.2 *Multi-Instrument Precision*—The multi-instrument standard deviation of a single test result has been found to be 0.015°. Therefore, the results of properly conducted measurements by different operators using different instruments in the same SGC should not differ by more than 0.04°.[5]

13.2 *Bias*—Since there is no accepted reference device suitable for determining the bias in this method, no statement of bias is made.

NOTE 12—ILS #151 conducted in 2007 indicated the two device types (DAVII-HMS and RAM) produced similar results on all SGC models listed.

14. Keywords

14.1 angle; asphalt; bituminous; compaction; gyratory; Superpave

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D04-1028.

[5] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C670.

APPENDIX

(Nonmandatory Information)

X1. SUPERPAVE GYRATORY COMPACTOR (SGC) INTERNAL ANGLE EVALUATION FORM

Superpave Gyratory Compactor

Manufacturer:__________________ Laboratory:__________________

Model:__________________ Location:__________________

Serial Number:__________________ Total Gyrations:__________________

Mold Temperature:__________________

Consolidation Pressure:__________________

Angle Measurement Instrument

Make and Model:__________________ Date of Previous Calibration:__________________

Serial Number:__________________ Next Calibration Date:__________________

Tilting Moment (N-m): __________________

Internal Angle Measurements

Position Measured	Angle (report to nearest 0.01°)	Results
Top #1	__________________	
Top #2	__________________	
Top #3	__________________	Average Top Angle:__________________
Bottom #1	__________________	
Bottom #2	__________________	
Bottom #3	__________________	Average Bottom Angle:__________________
		Effective Internal Angle:__________________

Technician: ______________________________ Date: ______________________________

(sign here)