Standard Test Method for
Compaction and Shear Properties of Bituminous Mixtures by Means of the U.S. Corps of Engineers Gyratory Testing Machine (GTM)[1]

This standard is issued under the fixed designation D 3387; 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 employs two separate modes of operation of the Gyratory Testing Machine (GTM), namely: (*a*) GTM fixed roller mode; and (*b*) GTM oil-filled roller mode. The fixed roller mode of operation is employed in testing for compaction and strain indices only, while the oil-filled roller mode of operation is employed in testing for strength properties as well as compaction and strain indices. This test method is for use with mixtures containing asphalt cement, asphalt cut-back, asphalt emulsion, or tar and aggregate up to 1 in. (25.4 mm) maximum size in the 4-in. (101.6-mm) diameter specimen and 1.5 in. (38.1 mm) maximum size in the 6-in. (152.4-mm) diameter specimen.

1.2 *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:*
C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates[2]
C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[2]

3. Terminology

3.1 *Definitions:*

3.1.1 *gyrograph*—a recording of shear strain experienced by the bituminous mixture during the compaction test (see Fig. 1).

3.1.2 *gyratory angle*—a measure of the magnitude of the gyratory strain. Three pertinent angles are defined as follows:

3.1.2.1 Initial gyratory angle or shear strain (machine setting) θ_o(see Fig. 1),

3.1.2.2 Minimum gyratory angle or shear strain (minimum gyrograph band width) θ_i(see Fig. 1), and

3.1.2.3 Maximum gyratory angle or shear strain (maximum gyrograph band width) θ_{max} (see Fig. 1).

3.1.3 *gyratory stability index* (GSI)—the ratio of the maximum gyratory angle to the minimum gyratory angle (see Fig. 1).

3.1.4 *gyratory compactibility index* (GCI)—the ratio of the unit mass (total mix) at 30 revolutions of the GTM to the unit mass (total mix) at 60 revolutions of the GTM.

3.1.5 *gyratory shear strength (S_G)*—the shear resistance of the specimen which is, among other things, a function of the imposed vertical pressure and degree of strain (see Annex A1).

3.1.6 *gyratory shear factor* (GSF)—the ratio of the measured gyratory shear strength to the approximate theoretical maximum induced shear stress, that is, a factor of safety type index with regard to failure in simple shear for the defined loading conditions.

4. Significance and Use

4.1 Either mode of operation (fixed roller or oil-filled roller) is intended to be used for guidance in selection of the optimum bitumen content and establishing unit mass requirements; additionally the oil-filled roller mode of operation is intended for use in arriving at a shear strength factor (referred to as gyratory strength factor, GSF) with regard to shear under the load and strain conditions selected for the test. The procedure described here is for one selected degree of shear strain (in this case an initial gyratory angle of 1°) and some selected vertical pressure (in this case the anticipated tire contact pressure). Attention is called to the fact that the gyratory angle selected should relate to the anticipated pavement deflection. The 1° angle selected here should have wide application but should the pavement engineer select a different shear angle (such as a degree of shear strain), it should be so indicated in the report. It is essential that the vertical pressure correspond to the maximum anticipated tire contact pressure, since the theoretical stress for compaction and maximum induced shear used in determining the compaction requirements and the gyratory strength factor (GSF) is based on the concept of employing realistic loads for the test.

D 3387 – 83 (1996)

Date _____

Operator _____

Sample Identification   _Dense Graded Crushed Stone (3/4-in. max)_

Ram Pressure Gage Reading _202_

Vertical Pressure on Specimen _120 psi_

Aggregate Temp. _300 ± 5°F_

Bitumen Temp. _270 ± 5°F_

Compaction Temp. _250 ± 5°F_

Dry Batch Mass _1247.6 g_

Bitumen Mass _65.7 g_

Bitumen Content _5.0 %_
* (Use 0.303 for 4-in. diameter specimen.)
  (Use 0.1347 for 6-in. diameter specimen.)

$$\text{Unit Mass} = \frac{\text{Mass, g}}{\text{Height, in.}} \times 0.303^* \text{ lb/ft}^3$$
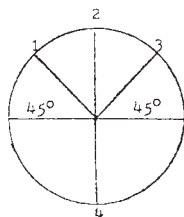
Initial Shear Strain, θ_o = _10/10_

Intermediate Shear Strain, θ_i = _14.3/10_

Maximum Shear Strain, θ_{max} = _15.0/10.0_ = 1.75 × _1.5°_ = _2.6_ %

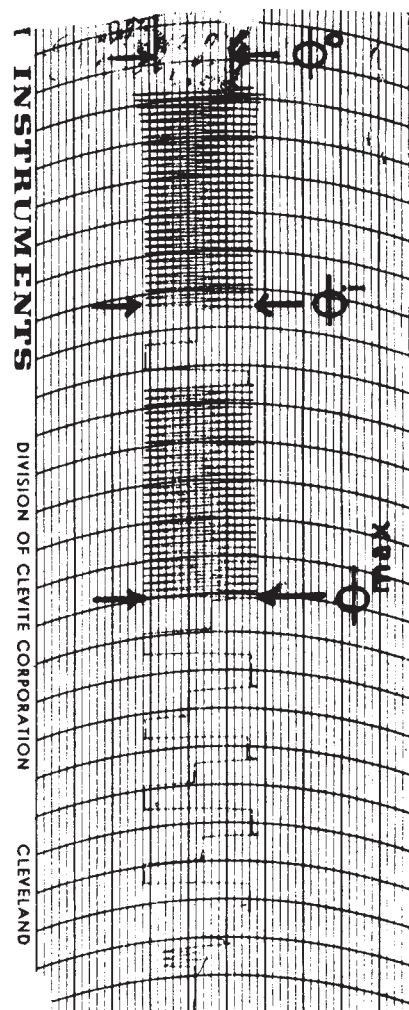Stability Index, θ_{max}/θ_i = _15.0/14.3_ = _1.05_

Attach Gyrograph Below

$$\text{Compactibility Index} = \frac{30 \text{ rev } \gamma_{TM}}{60 \text{ rev } \gamma_{TM}} = 0.989$$

γ_{TM} = Unit mass total mix
γ_{AO} = Unit mass aggregate only
$\gamma_{AO} = \gamma_{TM} \times$ percent aggregate

Roller Position

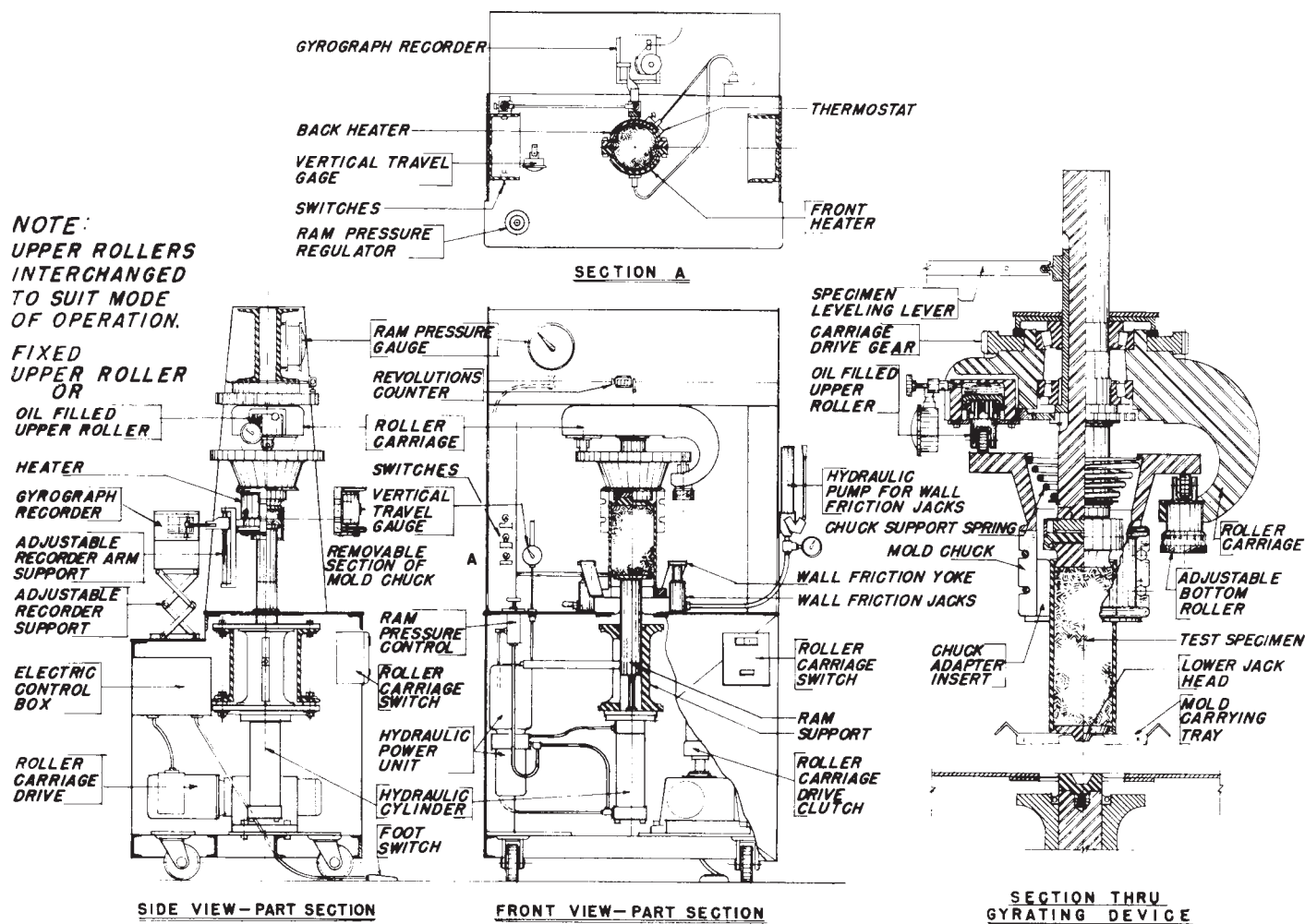| Rev.	Roller Pressure, psi				Temper-ature, °F	Unit Mass, lb/ft³	
	Specimen Height, in.						
	Height Gage Reading						
	Roller Position						
	1	3	4	Avg		Total Mix	Aggre-gate only
29 to 30	22	20	20	21	250	149.4	141.9
	2.665	2.662	2.664	2.664			
59 to 60	19	18	19	19	250	151.1	143.5
	2.635	2.634	2.633	2.634			

FIG. 1 GTM Compaction and Shear Test

FIG. 2 Gyratory Testing Machine

4.2 The gyratory strength factor (GSF) must be interpreted with due recognition of the use of the somewhat arbitrarily selected degree of strain and the assumption of plane maximum shear (the unit contact pressure divided by π) for a strip load on a homogeneous elastically isotropic mass.

4.3 The use of this method for guidance in the selection of the optimum bitumen content is limited to mixtures that are susceptible to the development of excess pore pressure when the voids become overfilled with bitumen. (This restriction does not apply to the gyratory strength factor, GSF.) A gyratory stability index (GSI), in excess of unity, indicates a progressive increase in plasticity during densification. An increase in this index indicates an excessive bitumen content for the compaction pressure employed and foretells instability of the bituminous mixture for the loading employed. A reduction in oil-filled roller pressure during the compaction process likewise indicates loss of stability because of overfilled voids; this phenomenon also serves as an indicator of maximum allowable bitumen content as does the widening of the gyrograph which gives a stability index in excess of unity.

4.4 The gyratory compactibility index (GCI) is an indicator of the compactibility of the mix. The closer this index approaches unity, the easier the mix is to compact.

5. Apparatus

5.1 *Gyratory Testing Machine (GTM) and Appurtenances*—The primary equipment for this test is the Gyratory Testing Machine (GTM)[3] and appurtenances. Fig. 2 is an assembly drawing of the machine (and appurtenant equipment) indicating essential features, including the wall friction apparatus and a schematic of the gyrating mechanism. The fixed upper roller and the oil-filled upper roller are interchangeable; the roller being selected to fit the mode of operation of the GTM.

5.2 *Ovens*—Ventilated ovens shall be provided for heating aggregates, bituminous material, and specimen molds and for curing cut-back mixes and emulsion mixes. It is recommended that the heating units be thermostatically controlled so as to maintain the required temperature within 5°F (2.8°C).

5.3 *Balances*, one having a capacity of 5 kg or more, sensitive to 1.0 g; and one having a capacity of 2 kg, sensitive to 0.1 g.

---

[3] A novel mechanization of the original Texas gyratory principle. This machine is manufactured by Engineering Developments Co., Inc. of Vicksburg, MI 39180, under letters Patent Nos. 2972249 and 3478572.

5.4 *Thermometers*—Armored glass or dial-type thermometers with metal stems are recommended. A range from 50 to 400°F (9.9 to 20.4°C) with sensitivity of 5°F (2.8°C) is required.

5.5 *Spacer Blocks*, two metal spacer blocks for use in zeroing the specimen height measuring equipment. These shall all be of 2-in. (50.8-mm) diameter with one each of the following lengths: 2.50± 0.005 in. (63.50 ± 0.013 mm) and 3.75 ± 0.005 in. (95.25 ± 0.013 mm).

5.6 *Miscellaneous Apparatus*—Trowels, spatulas, scoops, gloves, rubber gloves, metal pans, 4-in. (101.6-mm) diameter paper disks, and 6-in. (152.4-mm) diameter paper disks.

6. Test Specimens

6.1 *Selection of Bitumen Content for Specimens*—Conduct laboratory tests for one specimen each at a minimum of three bitumen contents, one above, one below, and one at the estimated optimum content (see Note 1). The incremental change of bitumen content should generally be 0.5 %. For extremely critical mixes, lower the incremental change of bitumen content to 0.3 % and for highly absorptive aggregates, increase the incremental change of bitumen content to 1.0 %. Tests on additional bitumen contents should be conducted as necessary when check tests are needed.

6.2 *Preparation of Aggregates*—In accordance with Test Method C 136, obtain a sieve analysis on the fine and coarse aggregate (aggregate shall be separated by means of a No. 4 (4.75-mm) sieve). Separate the aggregate into the various size fractions necessary for accurately recombining into test mixtures conforming to specified grading requirements.

6.3 *Preparation of Mixtures*—Combine the moisture-free aggregates into batches sufficiently large to make specimens approximately 2.50 in. (63.5 mm) long in the 4-in. (101.6-mm) diameter mold and 3.75 in. (95.3 mm) long in the 6-in. (152.4-mm) diameter mold. For normal aggregates, this will require approximately 1200 g for the 4-in. (101.6-mm) diameter specimens and approximately 4050 g for the 6-in. (152.4-mm) diameter specimens. Heat the aggregate to the proper mixing temperature; then weigh the required amount of bitumen at the proper temperature into the aggregate mixture. Mixing of the aggregate and bitumen shall be as thorough and rapid as possible; mechanical mixing is recommended.

NOTE 1—A first approximation of the optimum amount of bitumen for the aggregate may be determined by any method commonly employed by the laboratory. A method that has been found suitable in some laboratories is the centerfuge kerosene equivalent method.[4]

6.3.1 For mixes employing penetration/viscosity grades of asphalt, the temperature of the aggregate and asphalt at the

---

[4] California Highways and Public Works, Vol 20, No. 7, July 1942, pp. 14-17.

Date _____

Operator _____

Compaction *120 psi, 1°, 60 Rev.*

Sample Identification *Dense Graded Crushed Stone (¾-in. max)*

τ_{max} = Vertical Pressure/π = 120/3.14 = 38.2 *psi*   Machine Correction to S_G = −10 *psi*

θ_o = 10/10 = 1.0° = 1° 0′;   Tan θ_o = 0.0175

Bitumen Content, %	Vertical Pressure Gage Reading, psi	Total Vertical Pressure, psi	Specimen Height, h, in.				Roller Pressure Gage Reading, p, psi			
			1	3	4	Avg	1	3	4	Avg
4.5	202	120	2.648	2.640	2.642	2.64	21	18	21	20
5.0	202	120	2.635	2.634	2.633	2.63	19	18	19	19
5.5	202	120	2.606	2.604	2.606	2.61	13	14	14	14

θ_{max}, deg	θ_{max}/θ_o	Wall Friction Gage Reading, psi	Wall Friction 3.82 F or 2.55 F^A	Total Vertical Load, V, lb	b $h \cdot \tan \theta_o$	$V \cdot b$	90.0 p or 50.0 p^A	28.26 h or 12.65 h^A	Shear, S_G, psi		GSF S_G/τ_{max}
									Uncorrected	Corrected	
1.42	1.42	60	230	1507	0.046	69	1800	33	71	61	1.6
1.50	1.50	100	434	1507	0.046	69	1710	33	61	51	1.3
1.68	1.68	120	536	1507	0.046	69	1260	33	40	30	0.8

^{A} Select term to match applicable formula.

TM Model 4C

4-in. diameter specimen

$$S_G = \frac{50\,p - 2.55\,F + V \cdot b}{12.56\,h} \left(\frac{\theta_{max}}{\theta_o} \right)$$

GTM Model 6B–4C

4-in. diameter specimen

$$S_G = \frac{90\,p - 2.55\,F + V \cdot b}{12.56\,h} \left(\frac{\theta_{max}}{\theta_o} \right)$$

6-in. diameter specimen

$$S_G = \frac{90\,p - 3.82\,F + V \cdot b}{28.26\,h} \left(\frac{\theta_{max}}{\theta_o} \right)$$

FIG. 3 GTM Shear Test

time of mixing should correspond to the temperatures antici-pated to be used at the plant during manufacture of the paving mix. These temperatures will generally be somewhere in the range of 250 to 325°F (121 to 149°C). Once the mixing temperature is selected, it should be so controlled that the viscosity of the bitumen will not vary more than ±50 cSt during the mixing process.

6.3.2 For tar mixtures, the temperature of the aggregate and tar at the time of mixing should correspond to the temperatures to be used at the plant during manufacture of the paving mix. This temperature will generally not exceed 225°F (107°C). Once the mixing temperature is specified, it should be so controlled that the viscosity of the tar will not vary more than ±5 Engler specific viscosity during the mixing process.

6.3.3 For mixtures employing liquid asphalts (cut backs or emulsions), the asphalt need not be heated but the aggregate should be dried to constant weight at 221 to 230°F (105 to 110°C). The liquid asphalt should be combined with the aggregate at room temperature. Following mixing, cure the loose mixture in a ventilated oven maintained at 221 to 230°F (105 to 110°C) for at least 12 h prior to compaction at this temperature. The mix may be stirred occasionally during curing to accelerate loss of volatiles.

6.4 *Size of Specimens*—The 4-in. (101.6-mm) diameter specimens shall be approximately 2.50 in. (63.5 mm) long. The 6-in. (152.4-mm) diameter specimens shall be approximately 3.75 in. (95.3 mm) long.

7. Calibration

7.1 See Annex A2.

8. Procedure

8.1 *General*—The GTM-fixed roller is employed when the compaction test only is required. The GTM oil-filled roller is employed when both the compaction test and the shear test are required. The oil-filled roller procedure is accomplished in sequential steps including the compaction test, shear test, and wall friction test as outlined in this section. (The procedure for determining the machine correction for S_G is presented in Annex A2.) When using the fixed roller, inapplicable portions of the following instructions are ignored.

8.2 *Compaction or Compaction and Shear Test*—Fig. 1 and Fig. 3 illustrate data sheets which are suitable for recording and calculating compaction or compaction and shear test results and for displaying the gyrograph (shear strain) recording. The gyratory strain angles θ_o, θ_i, and θ_{max} are indicated on the gyrograph displayed in Fig. 1. For this test, set the initial gyratory angle, θ_o, at 1°. Roller positions 2 and 4 (Fig. 1) are used in setting the initial gyratory angle, θ_o. A trial batch of mix is used in making the initial gyratory angle adjustment. Make
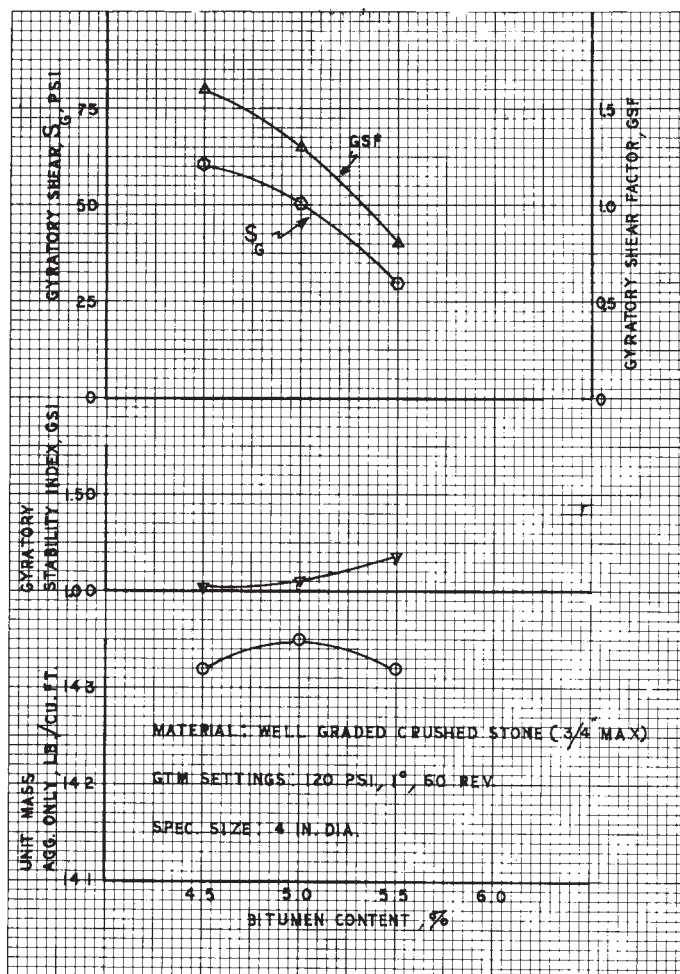

FIG. 4 Compaction and Shear Properties vs. Bitumen Content

certain that the specimen molds are thoroughly clean and free of defects. Excessive wear or grooving in the molds in the area of contact with the upper and lower plates will have an adverse effect upon the compaction as well as the gyrograph (shear strain) recording. Instructions for the compaction temperatures for the laboratory specimens are presented in 6.3.1 through 6.3.3. Set the GTM heater at 140°F (60°C) at least 15 min before starting the compaction test. Preheat the mold and base plate at 140°F (60°C). Place paper disks in the bottom of the mold and on top of the loose mix to prevent the bitumen from adhering to the end plates. Place the entire batch in the mold avoiding hand troweling or tamping as it is desired that the compaction process be completely mechanically controlled in order to attain the highest degree of precision and reproducibility. Use the mold-carrying tray to load the mold containing the mixture into the machine having first placed the wall friction yoke in position when employing the oil-filled roller mode of operation. Raise the ram and use a vertical pressure just sufficient to retain the specimen while the front of the mold chuck is tightened securely in position. When the mold chuck is securely tightened, increase the vertical pressure to the full compaction test pressure. Now bring the gyrograph recorder pin into contact and actuate the roller carriage and continue until 29 revolutions have been applied. At the completion of 29 revolutions, stop the carriage and record the specimen height and roller pressure readings (when required) at three positions 1, 3, and 4 (29 to 30 revolutions), as indicated in Fig. 1, thus completing 30 revolutions. Continue to apply additional revolutions until a total of 59 is reached. Again record height and roller pressure readings (when required) at three positions 1, 3, and 4 (59 to 60 revolutions) as indicated in Fig. 1, thus completing 60 revolutions. (Specimen height and roller-pressure reading may be taken at more frequent intervals of revolutions when more detailed delineation of these parameters is desired.)

8.3 *Wall Friction Test* (applicable when employing oil-filled roller mode of operation)—Immediately following the compaction and shear test, lower the vertical ram slightly so as to relieve the pressure on the bottom roller. Lower the bottom roller a sufficient number of turns to ensure that it will be out of contact with the mold chuck. (Keep account of the exact number of turns so that the roller can be again reset to exactly the same position.) Reapply the compaction pressure to the ram and cycle the roller carriage several times in order to level the specimen. With the compaction pressure still acting on the specimen, loosen the mold chuck bolts and remove the front section of the chuck so that the specimen mold is no longer restrained by the chuck. Install the two wall friction apparatus jacks beneath the wall friction yoke as illustrated in the assembly drawing, Fig. 2. With the vertical load acting on the specimen, the force required to overcome wall friction and move the mold with respect to the specimen shall be determined by observing the pressure gage of the jack while actuating the jack. The pressure reading will be found to increase with each thrust of the jack until there is sufficient force to move the mold with respect to the specimen. The pressure reading will then stabilize to about the same value after each thrust of the jack. The reading of the wall friction

gage shall be recorded in the space provided as illustrated in Fig. 3. Immediately after completion of the wall friction test, the test specimen should be removed from the GTM and the lower roller brought back to the 1° setting so that the machine is ready for the next test specimen.

9. Calculations

9.1 *Calculations for Compaction*—Calculate the following compaction properties for each specimen, as illustrated in Fig. 1: (*a*) unit mass, total mix; (*b*) unit mass, aggregate only; and (*c*) gyratory compactability index (GCI).

9.2 *Calculations for Shear*—Calculate the following gyratory shear properties (when applicable) as illustrated in Fig. 1 and Fig. 3: (*a*) gyratory stability index (GSI); (*b*) gyratory shear (S_G); and (*c*) gyratory shear factor (GSF).

10. Graphical Presentation

10.1 For convenience of analysis, the parameters calculated in Section 9 may be plotted against bitumen content. The graphs may be to any convenient arithmetic scales as illustrated in Fig. 4.

11. Report

11.1 The report shall include the following parameters for each specimen tested using either the fixed roller or the oil-filled roller mode of operation:

11.1.1 Mixing temperature,

11.1.2 Viscosity of bitumen at mixing temperature (give range),

11.1.3 Compacting temperature,

11.1.4 Viscosity of bitumen at compacting temperature (give range),

11.1.5 Initial gyratory angle,

11.1.6 Vertical pressure,

11.1.7 Number of revolutions,

11.1.8 Unit mass total mix,

11.1.9 Unit mass aggregate only,

11.1.10 Gyratory stability index (GSI), and

11.1.11 Gyratory compactibility index (GCI).

11.2 In addition to the parameters in 11.1, the report shall include the following parameters for each specimen tested using the oilfilled roller mode of operation:

11.2.1 Gyratory shear strength (S_G), and

11.2.2 Gyratory strength factor (GSF).

12. Precision and Bias

12.1 Statistical data available at this time are limited to a series of within-laboratory tests by the U.S. Army Corps of Engineers Waterways Experiment Station. Tests were conducted on one high quality hot mix bituminous concrete consisting of a dense graded (¾ in. max) crushed limestone aggregate with 5.0 % (85 to 100 penetration) asphalt cement. A total of 50 compaction and shear tests were conducted by a single-operator on identically prepared samples over a 2-week period. Five samples were tested per day using the same five 4-in. diameter molds throughout the test series. All 50 samples were mixed prior to the start of testing and reheated to compaction temperature when needed.

D 3387 – 83 (1996)

12.2 The statistical data obtained from this investigation are presented in Tables 1-4 . The test results in Table 1 are based upon the 50 individual test measurements, while each result used in preparing Table 2 consisted of the average of 4 measurements, using a total of 48 tests.

12.3 It is to be noted that the improvement in precision when averaging four measurements is minimal for measurements of unit mass, GCI, and GSI but quite significant for measurements of S_G and GSF.

12.4 Use of these tabulations in judging the precision to test results must be limited to within-laboratory test on dense graded hot mix bituminous pavements. Precision criteria for other types of pavement mixes and between-laboratory results must await further investigations by Subcommittee D04.20 of ASTM Committee D-4.

TABLE 1 Within-Laboratory Statistical Analysis Single Test Measurements (50 Tests) Dense Graded Hot Mix Bituminous Concrete

Measured Property	Mean	Standard Deviation	Difference Two-Sigma Limit	Difference Two-Sigma Limit, %
Unit mass, 30 rev	148.4	0.53	1.5	1.0 %
Unit mass, 60 rev	150.7	0.46	1.3	0.9 %
Gyratory compactibility index (GCI)	0.985	0.001	0.003	0.3 %
Gyratory stability index (GSI)	1.04	0.01	0.03	2.7 %
Gyratory shear (S_g)	109	7.56	21	20 %
Gyratory shear factor (GSF)	2.39	0.14	0.4	17 %

7

ASTM D 3387 – 83 (1996)

TABLE 2 Within-Laboratory Statistical Analysis Average of Four Test Measurements (48 Tests) Dense Graded Hot Mix Bituminous Concrete

Measured Property	Mean	Standard Deviation	Difference Two-Sigma Limit	Difference Two-Sigma Limit, %
Unit mass, 30 rev	148.4	0.40	1.13	0.8 %
Unit mass, 60 rev	150.7	0.21	0.59	0.4 %
Gyratory compactibility index (GCI)	0.985	0.0008	0.0024	0.2 %
Gyratory stability index (GSI)	1.04	0.0036	0.0101	1.0 %
Gyratory shear (S_g)	109	4.40	12	11 %
Gyratory shear factor (GSF)	2.4	0.05	0.14	6 %

TABLE 3 Within-Laboratory Statistical Analysis Single Test Measurements (50 Tests) Dense Graded Hot Mix Bituminous Concrete

Measured Property	Standard Deviation[A]	Difference Two-Sigma Limit[A]
Unit mass, 30 rev	0.53	1.5
Unit mass, 60 rev	0.46	1.3
Gyratory compactibility index (GCI)	0.001	0.003
Gyratory stability index (GSI)	0.01	0.03
Gyratory shear (S_g)	7.56	21
Gyratory shear factor (GSF)	0.14	0.4

[A]These numbers represent, respectively, the (1S) and (D2S) limits as described in Practice C 670.

TABLE 4 Within-Laboratory Statistical Analysis Average of Four Test Measurements (48 Tests) Dense Graded Hot Mix Bituminous Concrete

Measured Property	Standard Deviation[A]	Difference Two-Sigma Limit[A]
Unit mass, 30 rev	0.40	1.13
Unit mass, 60 rev	0.21	0.59
Gyratory compactibility index (GCI)	0.0008	0.0024
Gyratory stability index (GSI)	0.0036	0.0101
Gyratory shear (S_g)	4.40	12
Gyratory shear factor (GSF)	0.05	0.14

[A]These numbers represent, respectively, the (1S) and (D2S) limits as described in Practice C 670.

ANNEXES

(Mandatory Information)

A1. DEVELOPMENT OF THE FORMULA FOR GYRATORY SHEAR, S_G

A1.1 Referring to the schematic in Fig. A1.1 and taking moments about 0, the equation for gyratory shear, S_G, is developed as follows:

$$2 \cdot P \cdot L = S_G \cdot A \cdot h + 2 \cdot F \cdot a - N \cdot b \qquad (A1.1)$$

$$S_G = \frac{2(P \cdot L - F \cdot a) + N \cdot b}{A \cdot h}$$

A1.2 The equation in A1.1 is for the θ_o position; since the shear at the θ_{max} position is desired, it is approximated by assuming a linear stress-strain relationship and multiplying the previously calculated value by the ratio θ_{max}/θ_o so that the equation is then expressed as follows:

$$S_G = \frac{2(P \cdot L - F \cdot a) + N \cdot b}{A \cdot h}\left(\frac{\theta_{max}}{\theta_o}\right) \qquad (A1.2)$$
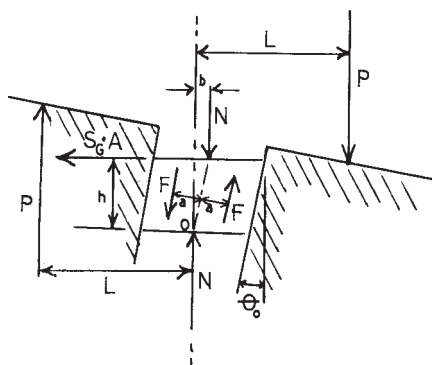
D 3387 – 83 (1996)

FIG. A1.1 Development of Formula for Gyratory Shear

where:
P = load on upper roller,
L = distance from center of path of upper roller to vertical axis through center of sample,
N = normal vertical load on specimen and is equal to the total load on ram,
A = end area of specimen,
h = height of specimen,

θ_o = initial gyratory shear angle,
θ_{max} = maximum gyratory shear angle,
a = $0.637 \times$ radius of mold (distance to the center of gravity for a circular arc equal to one half of the periphery),
B = arm of vertical force couple = $h \cdot \tan \theta_o$, and
F = force caused by wall friction.

A2. GYRATORY MACHINE CORRECTION

A2.1 In the conduct of shear tests with the gyratory testing machine, it has been found necessary to make machine corrections for the gyratory shear value S_G. This correction simply amounts to shifting the Mohr's type diagram for test results on a cohesionless material sufficiently to cause the envelope to pass through the origin of the Mohr's diagram. The cohesionless material used for this test is standard dry Ottawa sand, all passing a No. 20 (0.84-mm) sieve and retained on a No. 40 (0.42-mm) sieve. A correction is needed for each combination of compaction pressure and gyratory angle used in the GTM compaction and shear test. The test procedure for finding the GTM machine correction is illustrated in Figs. A2.1-A2.3. The dry Ottawa sand is first compacted under the same pressure, gyratory angle, and number of revolutions as scheduled for the compaction and shear test on a given bituminous mixture. The shear test on the dry sand is then conducted for at least three different magnitudes of vertical pressure; starting at some lower value, including an intermediate value, and finally using the same value that was used for compaction. The roller carriage is cycled once subsequent to each incremental adjustment in vertical pressure and prior to reading the upper roller values under that pressure.

D 3387 − 83 (1996)

Date _____

Operator _____

Sample Identification _Dry Ottawa Sand (<20 >40)_

Ram Pressure Gage Reading _202_   Vertical Pressure on Specimen _120 psi_

Aggregate Temp. . . . . .Bitumen Temp. . . . . .Compaction Temp. _Room_

Dry Batch Mass _900.0 g_   Bitumen Mass . . . . .Bitumen Content _0.0_
          * (Use 0.303 for 4-in. diameter specimen.)
          (Use 0.1347 for 6-in. diameter specimen.)

Unit Mass $= \dfrac{\text{mass, g}}{\text{height, in.}} \times 0.303^{*}$ lb/ft^3.

Initial Shear Strain, $\theta_o = $ _10/10_   Intermediate Shear Strain, $\theta_I = $ _12.2/10.0_

Maximum Shear Strain, $\theta_{max} = $ _12.2/10.0_ $= 1.75 \times$ _1.22°_ $= $ _2.1 %_

Stability Index $= \theta_{max}/\theta_I = $ _12.2/12.2_ $= $ _1.00_

Compactibility Index $= \dfrac{30 \text{ Rev. } \gamma}{60 \text{ Rev. } \gamma} = $ _____

Attach Gyrograph Below
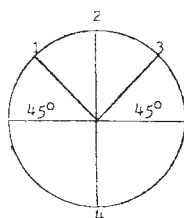
γ_{TM} = Unit Mass Total Mix
γ_{AO} = Unit Mass Aggregate Only
$\gamma_{AO} = \gamma_{TM} \times$ % Aggregate

Roller Position

	Roller Pressure, psi				Temper-ature, °F	Unit Mass, lb/ft^3	
	Specimen Height, in.						
	Height Gage Reading						
	Roller Position						
Rev.	1	3	4	Avg		Total Mix	Aggre-gate only
29 to 30	24	20	22	22	room	95.4	95.4
	2.830	2.840	2.900	2.857			
59 to 60	25	20	22	22	room	98.6	98.6
	2.768	2.762	2.767	2.766			

FIG. A2.1 GTM Compaction Test on Dry Ottawa Sand

10

D 3387 – 83 (1996)

Date_____

Operator _____

GTM SHEAR TEST

Compaction *120 psi; 1°; 60 rev.*

Sample Identification *Dry Ottawa Sand (<20, >40)*

τ_{max} = Vertical Pressure/π = *120/3.14 = 38.2 psi* Machine Correction to S_G = *−10 psi*

θ_o = *10/10 = 1.0° = 1° 0'*; Tan θ_o = *0.0175*

Bitumen Content, %	Vertical Pressure Gage Reading, psi	Total Vertical Pressure, psi	Specimen Height, h, in.				Roller Pressure Gage Reading, p, psi			
			1	3	4	Avg	1	3	4	Avg
0.0	90	50	2.776	2.768	2.771	2.77	12	9	11	11
0.0	150	88	2.770	2.765	2.769	2.77	18	14	17	16
0.0	202	120	2.766	2.761	2.765	2.77	22	19	23	21

θ_{max}, deg	θ_{max}/θ_o	Wall Friction Gage Reading, psi	Wall Friction 3.82 F or 2.55 F^A	Total Vertical Load V, lb	b $h \cdot \tan \theta_o$	$V \cdot b$	90.0 p or 50.0 p^A	28.26 h or 12.56 h^A	Shear, S_G, psi		GSF S_G/τ_{max}
									Uncorrected	Corrected	
1.25	1.25	55	204	628	0.048	30	990	35	29	...	...
1.25	1.25	70	281	1105	0.048	53	1440	35	43	...	...
1.25	1.25	88	372	1507	0.048	72	1890	35	57	...	...

^{A} Select term to match applicable formula.

TM Model 4C

4-in. diameter specimen

$$S_G = \frac{50\,p - 2.55\,F + V \cdot b}{12.56\,h} \left(\frac{\theta_{max}}{\theta_o} \right)$$

GTM Model 6B-4C

4-in. diameter specimen

$$S_G = \frac{90\,p - 2.55\,F + V \cdot b}{12.56\,h} \left(\frac{\theta_{max}}{\theta_o} \right)$$

6-in. diameter specimen

$$S_G = \frac{90\,p - 3.82\,F + V \cdot b}{28.26\,h} \left(\frac{\theta_{max}}{\theta_o} \right)$$

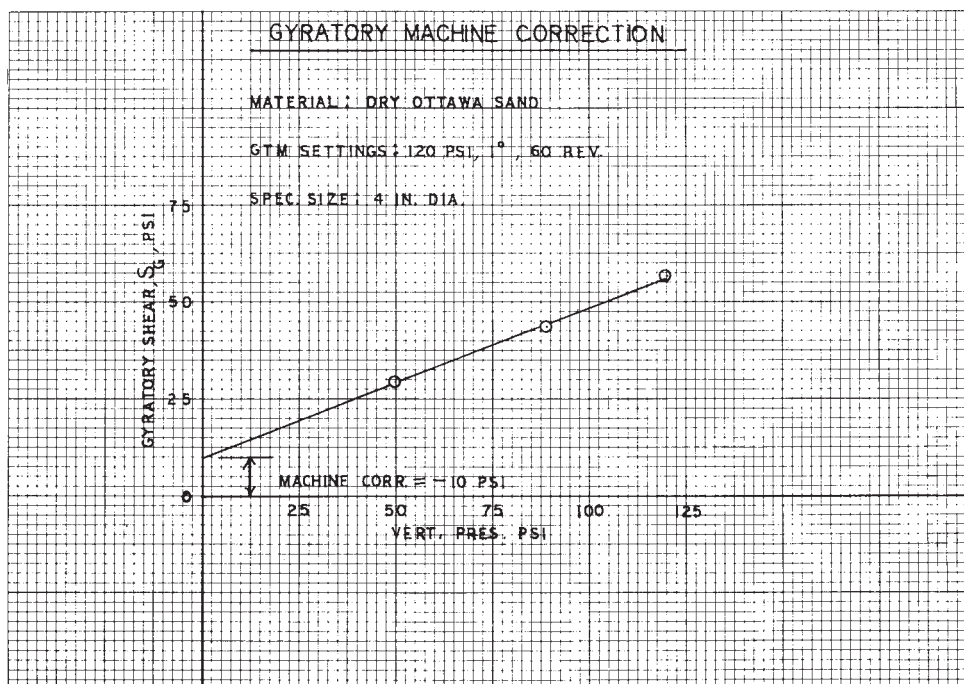**FIG. A2.2 GTM Shear Test**

11

ASTM D 3387 – 83 (1996)

FIG. A2.3 Gyratory Machine Correction