



Designation: D 3387 – 83 (Reapproved 1996)

Standard Test Method for Compaction and Shear Properties of Bituminous Mixtures by Means of the U.S. Corps of Engineers Gyrotory 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 Gyrotory 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 Aggregates²
- C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials²

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_0 (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) $\theta_{\max}$ (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 compactability 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.

¹ This test method is under the jurisdiction of ASTM Committee D-4 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.26 on Fundamental/Mechanistic Tests.

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² *Annual Book of ASTM Standards*, Vol 04.02.



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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, $\theta_o = 10/10$

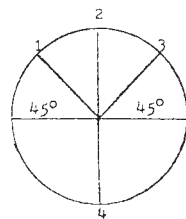
Intermediate Shear Strain, $\theta_i = 14.3/10$

Maximum Shear Strain, $\theta_{\max} = 15.0/10.0 = 1.75 \times 1.5^\circ = 2.6\%$

Stability Index, $\theta_{\max}/\theta_i = 15.0/14.3 = 1.05$

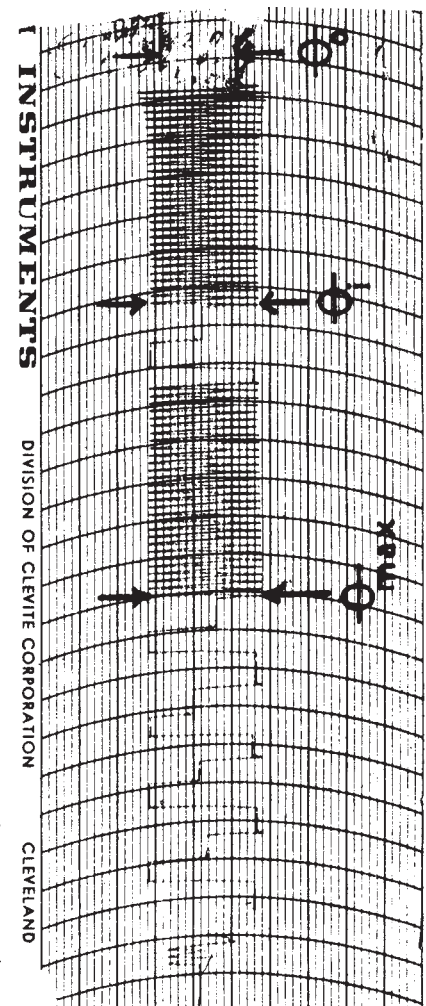
Compactibility Index = $\frac{30 \text{ rev } \gamma_{\text{TM}}}{60 \text{ rev } \gamma_{\text{TM}}} = 0.989$

Attach Gyrograph Below



Roller Position

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



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

FIG. 1 GTM Compaction and Shear Test

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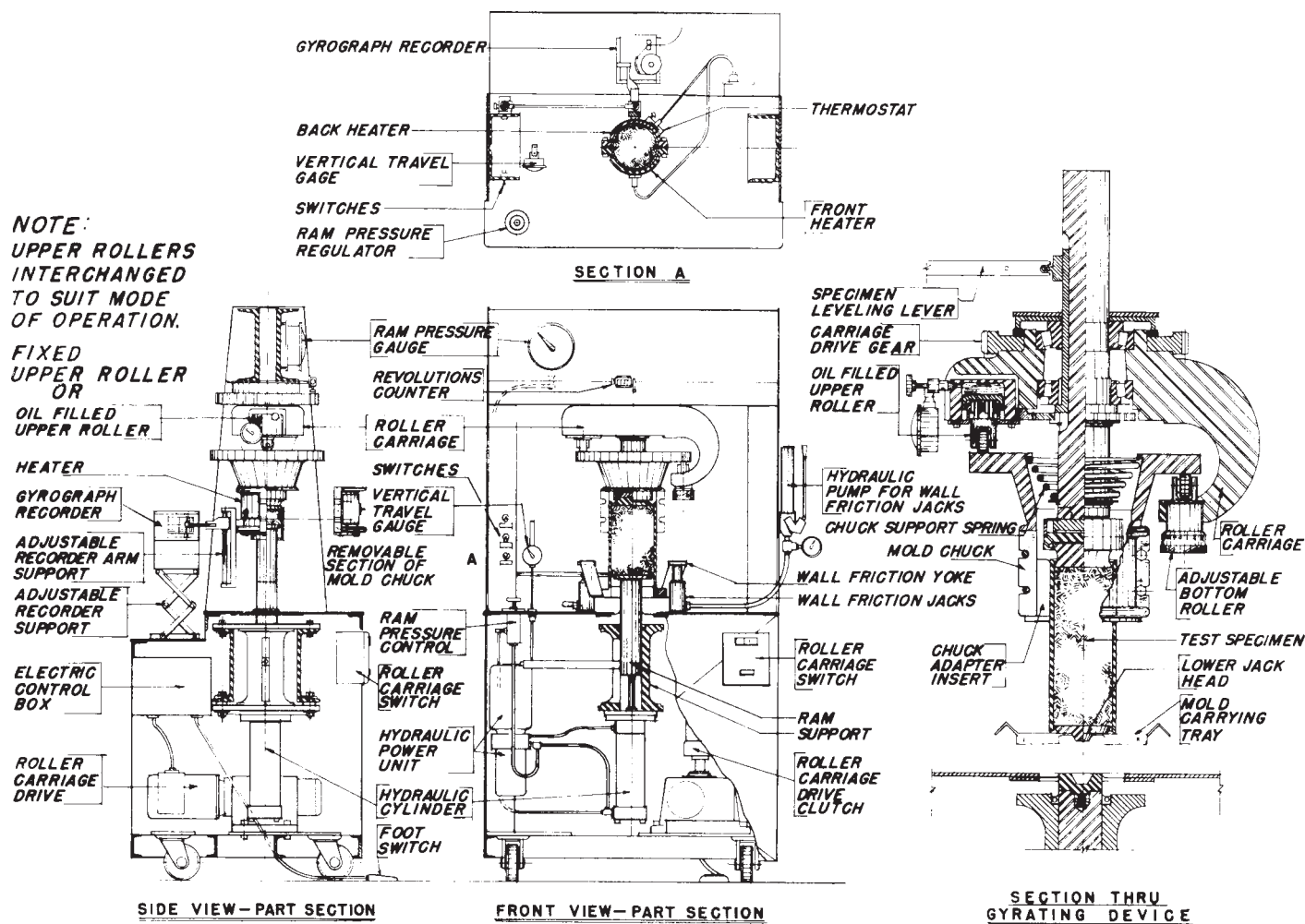


FIG. 2 Gyratory Testing Machine

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.

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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)

$\tau_{\max} = \text{Vertical Pressure}/\pi = 120/3.14 = 38.2 \text{ psi}$ Machine Correction to $S_G = -10 \text{ psi}$

$\theta_o = 10/10 = 1.0^\circ = 1^\circ 0'$; $\tan \theta_o = 0.0175$

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

$\theta_{\max}$, deg	$\theta_{\max}/\theta_o$	Wall Friction Gage Reading, psi	Wall Friction 3.82 F or 2.55 F ^A	Total Vertical Load, V, lb	b h · tan θ_o	V · b	90.0 p or 50.0 p ^A	28.26 h or 12.65 h ^A	Shear, S_G , psi		GSF $S_G/\tau_{\max}$
									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