Standard Method of Test for

Compressive Strength of Hot Mix Asphalt

AASHTO Designation: T 167-10

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

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1. SCOPE

1.1. This test method provides a method for measuring the compressive strength of compacted asphalt mixtures. It is for use with specimens weighed, batched, mixed, and fabricated in the laboratory, as well as for mixtures manufactured in a hot mix plant.

1.2. The values stated in SI units are to be regarded as the standard. The values given in parentheses are provided for information only.

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. *AASHTO Standards*:

- M 231, Weighing Devices Used in the Testing of Materials
- T 2, Sampling of Aggregates
- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 40, Sampling Asphalt Materials
- T 166, Bulk Specific Gravity of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
- T 168, Sampling Bituminous Paving Mixtures
- T 201, Kinematic Viscosity of Asphalts (Bitumens)
- T 209, Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt (HMA)
- T 248, Reducing Samples of Aggregate to Testing Size
- T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
- T 316, Viscosity Determination of Asphalt Binder Using Rotational Viscometer

2.2. *ASTM Standards*:

- C 670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- D 341, Standard Practice for Viscosity-Temperature Charts for Liquid Petroleum Products
- D 2493/D 2493M, Standard Viscosity-Temperature Chart for Asphalts
- D 1075, Standard Test Method for Effect of Water on Compressive Strength of Compacted Bituminous Mixtures
- E 4, Standard Practices for Force Verification of Testing Machines

2.3. *Federal Specification*:

- Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects

3. SIGNIFICANCE AND USE

3.1. The compressive strength of specimens prepared and tested by this test method along with density and voids properties are used for laboratory mix design of asphalt mixtures.

3.1.1. This test method also describes methods that can be used for molding, curing, and testing of specimens being evaluated by ASTM D 1075.

3.1.2. When used in conjunction with other mixture physical properties, the compressive strength may contribute to the overall mixture characterization and is one factor determining its suitability for use under given loading conditions and environment as a highway paving material.

3.2. Typical values of minimum compressive strengths for design of asphalt mixtures by this test method for different traffic densities are given in Table 402-1 of the "Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, 2003." Some state departments of transportation and Federal agencies have specific requirements of their own based on their experience with this test method. The agencies should be consulted for their specific requirements if work is to meet their standards.

3.3. Reheated field mixtures are permissible in this test method, but the resulting compressive strengths will be higher than for newly prepared mixtures due to the change in the binder viscosity, an element of the compressive strength as measured under these loading conditions and temperature (Note 4).

4. APPARATUS

4.1. *Molds and Plungers*—Molds and plungers shall be as follows:

4.1.1. The molding cylinder shall have sufficient height to allow fabrication of a 101.6 by 101.6 mm (4 by 4 in.) specimen. It shall have an inside diameter of 101.60 to 101.73 mm (4.000 to 4.005 in.) and a nominal wall thickness of 6.4 mm ($^1/_4$ in.).

4.1.2. The mold plungers shall pass through the mold freely and shall have a diameter within 1.27 mm (0.050 in.) of the mold's inside diameter. The plungers may be solid, hollow, or other structure as long as the ends are at least 12.7 mm ($^1/_2$ in.) thick and are at a right angle to the mold wall. The bottom plunger must be within 50 ± 4 mm (2 ± $^1/_8$ in.) high, but the top plunger may be any suitable height.

4.1.3. *Specimens Other Than 101.6 by 101.6 mm (4 by 4 in.)*—Molds and plungers for fabricating these size specimens may be used in accordance with Section 6.

4.2. *Supports*—Temporary supports shall be provided to raise the molding cylinder 25.4 mm (1 in.) during the molding operation. Steel bars 25.4 mm (1 in.) square are suitable.

4.3. *Testing Machine*—The testing machine must be of any type of sufficient capacity that will provide a range of accurately controllable rates of vertical deformation. Because the rate of vertical deformation for the compression test is specified as 0.05 mm/min·mm (0.05 in./min·in.) of specimen height, and it may be necessary to test specimens ranging in size from 50.8 by 50.8 mm

(2 by 2 in.) to perhaps 203.2 by 203.2 mm (8 by 8 in.) in order to maintain the specified minimum ratio of specimen diameter to particle size, the testing machine should have a range of controlled speeds covering at least 2.5 mm (0.1 in.)/min for 50.8-mm (2-in.) specimens to 10.2 mm (0.4 in.)/min for 203.2-mm (8-in.) specimens. The testing machine shall conform to the requirements of ASTM E 4. The testing machine shall be equipped with two steel bearing blocks with hardened faces, one of which is spherically seated and the other plain. The spherically seated block shall be mounted to bear on the upper surface of the test specimen and the plain block shall rest on the platen of the testing machine to form a seat for the specimen. The bearing faces of the plates shall have a diameter slightly greater than that of the largest specimens to be tested. The bearing faces, when new, shall not depart from a true plane by more than 0.0127 mm (0.0005 in.) at any point and shall be maintained within a permissible variation limit of 0.025 mm (0.001 in.). In the spherically seated block, the center of the sphere shall coincide with the center of the bearing face. The movable portion of this block shall be held closely in the spherical seat, but the design shall be such that the bearing face can be rotated freely and tilted through small angles in any direction.

4.4. *Oven*—The oven used in the preparation of materials or reheating of mixtures shall be controllable within ±3°C (±5°F) of any specified temperature above ambient up to 200°C (392°F).

4.5. *Hot Plate*—A small hot plate equipped with a rheostat shall be provided for supplying sufficient heat under the mixing bowl to maintain the aggregate and asphalt material at the desired temperature during mixing.

4.6. *Hot Water Bath or Oven*—A water bath or oven sufficiently large to hold three sets of 101.6-mm (4-in.) molds and plungers. If the water bath does not have an internal temperature control, a hot plate of sufficient capacity with a control to maintain the water bath at a temperature just under the boiling point will be required. The oven shall be capable of maintaining a temperature of 93.3 to 135°C (200 to 275°F).

4.7. *Air Bath*—The air bath shall be thermostatically controlled and shall maintain the air temperature for storing the specimens at 25 ± 0.5°C (77 ± 1.0°F) immediately prior to performing the compression test.

4.8. *Balance*—The balance shall have sufficient capacity, be readable to 0.1 percent of the sample mass, or better, and conform to the requirements of M 231.

4.9. *Mixing Machine*—Mechanical mixing is preferable to hand mixing. Any type of mixer may be used, provided it can maintain the mixture at the required mixing temperature and will produce a well-coated, homogeneous mixture of the required size in 2 minutes or less, and further provided that it is of such design that fouling of the blades will be minimized and each individual batch can be retrieved in essentially its entirety, including asphalt and fines. Hand mixing is allowable, if necessary, but for hot mixtures the time required to obtain satisfactory coating is often excessive, and generally the test results are less uniform than when machine mixing is employed.

4.10. *Spatulas*—A flexible spatula for scraping the mixing bowl and a stiff spatula for spading the specimen in the mold.

5. PREPARATION OF TEST MIXTURES

5.1. Limit the size of the individual batches to the amount required for one test specimen.

5.2. Mix an initial batch for the purpose of "buttering" the mixing bowl and stirrers. Empty this batch after mixing and clean the sides of the bowl and stirrers of mixture residue by scraping with a small limber spatula. Do not wipe with cloth or wash clean with solvent, except when a change is to be made in the asphalt binder or at the end of a run.

5.3. Mold a trial specimen in order to determine the correct weight of materials to produce a specimen of the desired height. Use the initial or "buttering" batch for this purpose, if desired.

5.4. Aggregate ingredient samples shall be obtained in accordance with T 2 and reduced to the appropriate size by T 248. When preparing aggregates for batching, each reduced ingredient sample shall be separated into the desired size fractions in accordance with T 27. Agency practice will specify which sieves should be used to derive the desired fractions.

5.4.1. The Mixture Design, Job Mix Formula, or other control shall be used to combine the appropriate weight of each size from each ingredient aggregate to obtain the appropriate gradation and batch weight, and to determine the appropriate weight of asphalt binder to use for each specimen.

5.5. A representative sample of asphalt binder shall be obtained in accordance with T 40 from a representative stock of the material.

5.5.1. For unmodified asphalt binders, the temperature versus kinematic viscosity relationship for the asphalt binder involved dictates the temperature that should be used for preparing the hot mix asphalt test specimens. The mixing temperature is typically the temperature that yields 170 ± 20 centistokes of viscosity. The compacting temperature is typically the temperature that yields 280 ± 30 centistokes of viscosity. Mixing and compacting temperatures may be provided by the asphalt binder manufacturer (Note 1). Aggregate is heated no hotter than 28°C (50°F) above the mixing temperature to allow for dry mixing prior to adding the asphalt binder.

Note 1—Modified asphalt binders may not adhere to the equi-viscous ranges noted in Section 5.5.1. 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 (350°F).

5.5.2. The mixing and compacting temperatures are normally available from the asphalt binder supplier; however, it may be determined by testing the asphalt binder for kinematic viscosity (T 201) at two temperatures and plotting a graph showing the temperature and corresponding viscosity for each of the two points. Temperatures of 135°C (275°F) and 163°C (325°F) are convenient for asphalt binder grade PG 64-22; however, lower temperatures may be more appropriate for less viscous grades.

5.5.3. The graph paper may be a single or double cycle semi-log paper with the log axis (y) ranging from 100 to 1000 centistokes and the linear (x) axis established to cover the above two temperatures. Greater precision is derived by selecting ranges that utilize most of the page. General descriptions of the graph paper can be observed in ASTM D 2493/D 2493M and ASTM D 341.

5.6. *Laboratory-Mixed Material*—Preheat the bowl and batch of aggregate in an oven meeting the requirements of Section 4.4 to a temperature that complies with the aggregate temperature in Section 5.5. This will result in an acceptable temperature after dry mixing. With the bowl of aggregate resting on a balance, quickly pour the prescribed weight of hot asphalt binder onto the hot aggregate and immediately mix the asphalt binder into the aggregate (Section 4.9). If mixing by hand, this can be done with a large spoon by rolling the material from perimeter toward the center to maximize aggregate and asphalt contact and minimize asphalt contact with the bowl. The mixing should be completed within 90 to 120 seconds, during which time the temperature should have dropped to about 3 to 5°C (5 to 9°F) above the compacting temperature. As soon as the

material has been thoroughly mixed and has reached temperature within the specified range, charge the mold and compact the specimen.

Note 2—If the countertop is metal, an insulator such as paper may be used to reduce the rate of cooling.

5.6.1. When mixing is complete, the temperature of the mixture must be at least 3°C (5°F) above the compacting temperature; otherwise, discard the mixture and repeat mixing procedures according to Section 5.6, taking precautions to maintain temperature.

Note 3—Reheating may result in increased aging of the asphalt binder. Depending on the particular asphalt binder being tested, this can result in significantly higher-strength values.

Note 4—Laboratory samples prepared according to this test method may produce different test results, such as compressive strength values and percent air voids, when compared to results obtained from reheated plant-mixed field samples due to the effect of additional cure time and the absorption of asphalt binder by the aggregate in the field sample.

5.7. *Plant-Mixed Material*—Plant-mixed hot mix asphalt shall be sampled in accordance with AASHTO T 168 and reduced to slightly more than the amount needed to fabricate the specimen. The size reduction shall be in accordance with AASHTO T 248, Method B. Adjust the weight of the reduced sample to the required weight by removing and discarding a small amount of the mixture. Care must be exercised to discard both fine and coarse particles to maintain the proper gradations.

5.7.1. Place the weighed sample into an appropriate container and heat in an oven to the mixing temperature provided in Section 5.5 for the asphalt represented in the mixture. Thoroughly mix the mixture until the temperature is 3 to 5ºC (5 to 9ºF) above the compacting temperature. This will result in the mixture being at the compacting temperature when compacting begins.

5.7.2. Compacting may commence immediately, or the material may be placed into an oven for a short time to allow more efficient handling of multiple plant-mixed samples; however, a sample should not remain in the oven for more than 1 hour.

6. TEST SPECIMENS

6.1. Generally, the test specimens shall be cylinders 101.6 mm (4.0 in.) in diameter and 101.6 ± 2.5 mm (4.0 ± 0.1 in.) in height. It is recognized that the size of test specimens has an influence on the results of the compressive strength test. Cylindrical specimens of dimensions other than 101.6 mm (4.0 in.) diameter are allowable, provided that:

6.1.1. The height shall be equal to the diameter within ±2.5 percent;

6.1.2. The diameter shall be not less than four times the nominal diameter of the largest aggregate particles;

6.1.3. The diameter shall be not less than 50.8 mm (2 in.); and

6.1.4. The unit rate of deformation shall be kept constant during the compression test (Section 8).

7. MOLDING AND CURING TEST SPECIMENS

7.1. Wipe the molds and plungers with a clean cloth that has a few drops of oil on it. Place approximately one half of the mixture (laboratory-manufactured material according to Section 5.6, or reheated plant-mixed material according to Section 5.7) in the molding cylinder, which, together with the top and bottom plunger, has been preheated for at least 1 hour in the water bath maintained at a temperature just under the boiling point or preheated for at least 2 hours in an oven maintained at a temperature between 93.3 and 135°C (200 and 275°F). With the bottom plunger in place and the molding cylinder supported temporarily on the two steel support bars, spade the mixture vigorously 25 times with a heated spatula, with 15 of the blows being delivered around the perimeter of the mold to reduce honeycombing, and the remaining 10 at random over the mixture.

7.2. Quickly transfer the remaining half of the mixture to the molding cylinder and repeat a similar spading action. Penetrate the mixture with the spatula as deeply as possible. A spatula having a slightly curved cross section has been used to advantage by some laboratories. The top of the mixture must be slightly rounded or cone-shaped to aid in firm seating of the upper plunger.

7.3. Compress the mixture between the top and bottom plungers under an initial load of about 1 MPa (150 psi) to set the mixture against the sides of the mold. Remove the support bars to permit full double–plunger action and apply the entire molding load of 20.7 MPa (3000 psi) for 2 minutes. When specimens are to be tested in accordance with ASTM 1075 for loss of strength resulting from the action of water, the standard molding load of 20.7 MPa (3000 psi) may be increased or decreased to achieve a target air void percentage or percent density.

Note 5—Based on the specified area of the plunger used with a 101.6-mm (4-in) molding cylinder, 1 MPa (150 psi) is approximately 8.2 kN (1850 lb) and 20.7 MPa (3000 psi) is approximately 168 kN (37 700 lb).

Note 6—Alternate methods of compaction may be utilized provided approximately 7 percent air voids are achieved.

7.4. Remove the specimen from the mold with an ejection device that provides a smooth, uniform rate of travel for the ejection head.

7.5. After removal from the mold, oven-cure specimens for 24 hours at 60°C (140°F). In case specimens are to be stored dry for more than 24 hours from completion of oven curing to compression testing, protect them from exposure to the air by sealing them in closely fitting, airtight containers.

8. PROCEDURE

8.1. Allow the test specimens to cool at room temperature for at least 2 hours after removal from the curing oven; then determine the bulk specific gravity of each specimen in accordance with T 166.

8.2. Bring the test specimens to the test temperature 25 ± 1°C (77 ± 1.8°F) by storing them in an air bath maintained at the test temperature for not less than 4 hours.

8.3. Test the specimens in axial compression without lateral support at a uniform rate of vertical deformation of 0.05 mm/min·mm (or 0.05 in./min·in.) of height. For specimens 101.6 mm (4 in.) in height, use a rate of 5.08 mm/min (0.2 in./min). Specimen failure is defined as the maximum load experienced by the specimen during the compression process.

8.4. The theoretical specific gravity and density shall be determined by T 209, or by any other method deemed appropriate by the agency involved. If T 209 is used, a sample of the mixture prepared but not molded, and compacted may be used.

8.5. Calculate the percent air voids in each specimen in accordance with T 269.

9. REPORT

9.1. *Report the following information*:

9.1.1. The bulk specific gravity, theoretical maximum specific gravity, density, and percent air voids of the specimens;

9.1.2. The compressive strength in kilopascals (lb/in.^{2}), determined by dividing the maximum vertical load obtained during deformation at the rate specified in Section 8 by the original cross-sectional area of the test specimen. Not fewer than three specimens shall be prepared for each asphalt increment, and the average of the three shall be reported as the compressive strength; and

9.1.3. The nominal height and diameter of the test specimens.

9.1.4. The compaction method utilized.

10. PRECISION AND BIAS

10.1. *Single-Operator Precision*—The single-operator standard deviation of a single test result (where the test result is, as defined in this test method, the average of a minimum of three separate compressive strengths) has been found to be 145 kPa (21 psi) (Note 7). Therefore, results of two properly conducted tests (each consisting of the average of a minimum of three individual compressive strengths) in the same laboratory on the same material by the same operator should not differ by more than 407 kPa (59 psi) (Note 7), and the range (difference between highest and lowest) of the individual measurements used in calculating the average should not exceed 841 kPa (122 psi) (Note 8).

Note 7—These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM C 670.

Note 8—Calculated as described in ASTM C 670.

10.2. *Multilaboratory Precision*—The multilaboratory standard deviation of a single test result (where the test result is, as defined in this test method, the average of a minimum of three separate compressive strengths) has been found to be 372 kPa (54 psi) (Note 7.) Therefore, results of two properly conducted tests (each consisting of the average of a minimum of three individual compressive strengths) in different laboratories on the same material should not differ by more than 1055 kPa (153 psi).

Note 9—The precision statements given are applicable only to the static compaction method.

10.3. This test method has no bias because the compressive strength of asphalt mixtures is defined only in terms of the test method.

11. KEYWORDS

11.1. Asphalt paving mixtures; compression testing; compressive strength.