Hot Mix Asphalt

Plant Technician

Field Manual

Version 20

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Standard Practice for Sampling Aggregates

This standard is issued under the fixed designation D75/D75M; 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 practice covers sampling of coarse and fine aggregates for the following purposes:
   1.1.1 Preliminary investigation of the potential source of supply,
   1.1.2 Control of the product at the source of supply,
   1.1.3 Control of the operations at the site of use, and
   1.1.4 Acceptance or rejection of the materials.

   Note 1—Sampling plans and acceptance and control tests vary with the type of construction in which the material is used.

1.2 The text of this standard 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.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with 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.

   Note 2—The quality of the results produced by this standard 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 standard 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.

2. Referenced Documents

2.1 ASTM Standards:
   C125 Terminology Relating to Concrete and Concrete Aggregates
   C2702 Practice for Reducing Samples of Aggregate to Testing Size
   D8 Terminology Relating to Materials for Roads and Pavements
   D2234/D2234M Practice for Collection of a Gross Sample of Coal
   D3665 Practice for Random Sampling of Construction Materials
   D3666 Practice for Minimum Requirements for Agencies Testing and Inspecting Road and Paving Materials
   E105 Practice for Probability Sampling of Materials
   E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process
   E141 Practice for Acceptance of Evidence Based on the Results of Probability Sampling

3. Terminology

3.1 Definitions:
   3.1.1 maximum size of aggregate, n—in specifications for, or descriptions of aggregate—the smallest sieve opening through which the entire amount of aggregate is required to pass.
   3.1.2 maximum aggregate size, (Superpave) n—in specifications for, or descriptions of aggregate—one size larger than the nominal maximum aggregate size.
   3.1.3 nominal maximum aggregate size (of aggregate), n—in specifications for, or descriptions of aggregate—the smallest sieve opening through which the entire amount of the aggregate is permitted to pass.
   3.1.4 nominal maximum aggregate size (Superpave), n—in specifications for, or descriptions of aggregate—one size larger than the first sieve that retains more than 10 % aggregate.

1 This practice is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.30 on Methods of Sampling. Current edition approved June 1, 2014. Published June 2014. Originally approved in 1920. Last previous edition approved in 2009 as D75/D75M – 09. DOI: 10.1520/D0075_D0075M-14.

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.
3.1.4 Discussion—The definitions in 3.1.1 and 3.1.2 also appear in Terminologies C125 and D8. They are presented in this standard to illustrate the differences between the aggregate definitions and Superpave definitions of similar terms. The definitions in 3.1.2 and 3.1.4 apply to hot mix asphalt (HMA) mixtures designed using the Superpave system only.

3.1.4.2 Discussion—Specifications on aggregates usually stipulate a sieve opening through which all of the aggregate may, but not need to, pass so that a slated maximum portion of the aggregate may be retained on that sieve. A sieve opening so designed is the nominal maximum size.

4. Significance and Use

4.1 Sampling is equally as important as the testing, and the sampler shall use every precaution to obtain samples that will show the nature and condition of the materials which they represent.

4.2 Samples for preliminary investigation tests are obtained by the party responsible for development of the potential source (Note 3). Samples of materials for control of the production at the source or control of the work at the site of use are obtained by the manufacturer, contractor, or other parties responsible for accomplishing the work. Samples for tests to be used in acceptance or rejection decisions by the purchaser are obtained by the purchaser or his authorized representative.

Note 3—The preliminary investigation and sampling of potential aggregate sources and types occupies a very important place in determining the availability and suitability of the largest single constituent entering into the construction. It influences the type of construction from the standpoint of economics and governs the necessary material control to ensure durability of the resulting structure, from the aggregate standpoint. This investigation should be done only by a responsible trained and experienced person. For more comprehensive guidance, see the Appendix.

5. Securing Samples

5.1 General—Where practicable, samples to be tested for quality shall be obtained from the finished product. Samples from the finished product to be tested for abrasion loss shall not be subject to further crushing or manual reduction in particle size in preparation for the abrasion test unless the size of the finished product is such that it requires further reduction for testing purposes.

5.2 Inspection—The material to be sampled shall be visually inspected to determine discernible variations. If any discernible variations are noted, corrective action shall be taken to establish homogeneity in the material prior to sampling. If it is necessary to indicate the degree of variability existing within the main pile, separate samples shall be drawn from separate areas of the pile. The seller shall provide suitable equipment needed for proper inspection and sampling.

5.3 Procedure:

5.3.1 Sampling from a Flowing Aggregate Stream (Bins or Belt Discharge)—Select units to be sampled by a random method, such as Practice D3665, from the production. Obtain at least three approximately equal increments, selected at random from the unit being sampled, and combine to form a field sample whose mass equals or exceeds the minimum recommended in 5.4.2. Take each increment from the entire cross section of the material as it is being discharged. It is usually necessary to have a special device constructed for use at each particular plant. This device consists of a pan of sufficient size to intercept the entire cross section of the discharge stream and hold the required quantity of material without overflowing. A set of rails may be necessary to support the pan as it is passed under the discharge stream. Insofar as is possible, keep bins continuously full or nearly full to reduce segregation.

Note 4—Sampling the initial discharge or the final few tons from a bin or conveyor belt increases the chances of obtaining segregated material and should be avoided.

5.3.2 Sampling from the Conveyor Belt—Select units to be sampled by a random method, such as Practice D3665, from the production. Obtain at least three approximately equal increments, selected at random, from the unit being sampled and combine to form a field sample whose mass equals or exceeds the minimum recommended in 5.4.2. Stop the conveyor belt while the sample increments are being obtained. Insert two templates, the shape of which conforms to the shape of the belt in the aggregate stream on the belt, and space them such that the material contained between them will yield an increment of the required weight (see Fig. 1). Carefully scoop all material between the templates into a suitable container and collect the fines on the belt with a brush and dust pan and add to the container.

Note 5—Automatic belt samplers may be used as long as they are properly maintained, and regular inspection ensures all material is being removed from the belt (see Fig. 2).

5.3.3 Sampling from Stockpiles—Avoid sampling coarse aggregate or mixed coarse and fine aggregate from stockpiles whenever possible, particularly when the sampling is done for the purpose of determining aggregate properties that may be dependent upon the grading of the sample. If circumstances make it necessary to obtain samples from a stockpile of coarse aggregate or a stockpile of combined coarse and fine aggregate, design a sampling plan for the specific case under consideration to ensure that segregation does not introduce a bias in the results. This approach will allow the sampling agency to use a sampling plan that will give a confidence in results obtained therefrom that is agreed upon by all parties concerned to be
acceptable for the particular situation. The sampling plan shall define the number of samples necessary to represent lots and sublots of specific sizes. The sampling plan shall also define any specialized site-specific sampling techniques or procedures that are required to ensure unbiased samples for existing conditions. The owner and supplier shall agree upon the use of any specialized site-specific techniques or procedures. When site-specific techniques or procedures are developed for sampling a stockpile, those procedures shall supersede the procedures given in 5.3.3.1. (Note 6). General principles for sampling from stockpiles are applicable to sampling from trucks, rail cars, barges, or other transportation units.

Note 6—Specific site sampling plans may include the number of sampling increments (loader buckets) required to construct the sampling pad.

5.3.3.1 Sampling from Stockpiles with Power Equipment (preferred)—In sampling material from stockpiles it is very difficult to ensure unbiased samples due to the segregation which often occurs when material is stockpiled, with coarser particles rolling to the outside base of the pile. For coarse or mixed coarse and fine aggregate, every effort shall be made to enlist the services of power equipment to develop a separate small sampling pile.

1) When obtaining a sample from a stockpile for acceptance testing, a loader shall enter the stockpile nearest the area representing material that is currently being shipped or loaded into a production facility, with the bucket approximately 150 mm [6 in.] above ground level, never allowing the front tires of the loader to ramp up on the pile. Without backing up, the loader shall lift the full bucket of material then tilt the bucket down to gently roll the material out of the bucket back onto the pile, thus re-blending any segregated material on the outside surface of the pile. If prior visual inspection noted discernible variation, or if the loader is not of sufficient size to cause a cascading effect down the face of the pile during this remixing process, several buckets of material shall either be remixed or removed and discarded to prevent use of potentially injurious material.

2) After re-blending, the loader shall re-enter the stockpile, as before, and obtain a full loader bucket of the re-blended material, tilt back and lift the bucket only high enough to back up slightly.

3) At the base of the main stockpile with the bucket only high enough to permit free-flow of the material from the bucket, the loader operator shall tilt the bucket forward to gently roll the material out of the bucket forming a small sampling pile. If the loader bucket is not of sufficient size to create a sample pad of representative size, multiple buckets shall be used, dumped on top of each other and back-dragged to form a single sample pad.

4) At this point the loader operator shall raise the bucket, drive forward far enough to reach across the small pile with the loader bucket without allowing the loader tires to ramp up on the sampling pile, lower the bucket to about half the height of the small pile, and backup, therefore creating a flat surface for sampling (see Fig. 3). The loader shall only back-drag the small pile once. This flat surface provides a stable and safe area to obtain a representative sample.

5) Place the sample bucket(s) near the center of the flat, oval-shaped sampling pad. The sample shall be obtained across the entire flat area, but avoid sampling within 0.3 m [1 ft] of the sample pad edge. Divide the sample pad into 4 quadrants and sample equal amounts of materials evenly across each quadrant. Fully insert the shovel as vertical as possible then gently roll the shovel back and lift slowly to avoid coarse material rolling off the sides of the shovel (Note 7). Obtain additional shovelfuls from different quadrants of the sampling pad, and in areas that avoid previous "shovel holes."

Note 7—Square-tip shovels with the outer edges rolled up approximately 50 mm [2 in.] on each side works well in preventing material from rolling from the side. Spade-tip shovels are not recommended.

5.3.3.2 Sampling from Stockpiles Without Power Equipment:

Note 8—Sampling coarse aggregate and coarse and fine mixed aggregate stockpiles without the aid of power equipment is not advised.

1) Where power equipment is not available, samples from stockpiles shall be made up of at least three increments taken from the top third, at the mid-point, and bottom third of the elevation of the stockpile.

2) Shove a board vertically into the pile just above the sampling point to prevent coarser material from rolling down and further segregating the material and biasing the sample. The board shall be of ample size to prevent material from cascading down into the sampling area.

3) With the board in place, scrape off the outer most surface of the pile with the shovel, then insert the shovel perpendicular to the angle of the pile, into the freshly exposed material to obtain the sample. Repeat this process across the face of the stockpile until the recommended minimum field sample size in 5.4.2 is obtained but no less than the three increments described in 5.3.3.2(1).

5.3.3.3 Sampling Fine Aggregate from Stockpiles (Alternative Method for Fine Aggregate Only)—When sampling fine aggregate from a stockpile, the outer layer, which easily becomes segregated by wind and rain during stockpile storage, shall be removed and the sample taken from the material beneath.
Sampling tubes approximately 30 mm [1.25 in.] minimum by 2 m [6 ft.] in length shall be inserted into the shipping face of the stockpile horizontally at random locations.

NOTE 9—A sampling tube can be constructed of aluminum, PVC, or other sturdy material. The tip being inserted into the pile can be cut at a 45° angle to ease insertion.

(2) Sample shall be taken at a minimum height of 3 ft from the surrounding grade.

(3) A minimum of five tube insertions randomly spaced across the face of the stockpile shall form a single field sample (see Fig. 4). Ensure that the minimum field sample size recommended in 5.4.2 is obtained.

5.3.4 Sampling from Transportation Units—Avoid sampling coarse aggregate or mixed coarse and fine aggregate from transportation units whenever possible, particularly when the sampling is done for the purpose of determining aggregate properties that may be dependent upon the grading of the sample. If circumstances make it necessary to obtain samples from a transportation unit, design a sampling plan for the specific case under consideration to ensure that segregation does not introduce a bias in the results. This approach will allow the sampling agency to use a sampling plan that will give a confidence in results obtained therefrom that is agreed upon by all parties concerned to be acceptable for the particular situation. The sampling plan shall define the number of samples necessary to represent lots and sublots of specific sizes. General principles for sampling from stockpiles are applicable to sampling from trucks, rail cars, barges, or other transportation units.

NOTE 10—Sampling from transportation units should be avoided if at all possible. In sampling material from transportation units it is very difficult to ensure unbiased samples, due to the segregation which often occurs when material is transported, with coarser particles rolling to the outside and finer particles settling.

5.3.4.1 In sampling coarse aggregates from railroad cars or barges, effort shall be made to enlist the services of power equipment capable of exposing the material at various levels and random locations.

5.3.4.2 Where power equipment is not available, a common procedure requires excavation of three or more trenches using a shovel across the unit at points that will, from visual appearance, give a reasonable estimate of the characteristics of the load. The trench bottom shall be approximately level, at least 0.3 m [1 ft] in width and in depth below the surface.
5.3.4.3 A minimum of three increments from approximately equally spaced points along each trench shall be taken by pushing a shovel downward into the material.

5.3.4.4 Coarse aggregate in trucks shall be sampled in essentially the same manner as for rail cars or barges, except for adjusting the number of increments according to the size of the truck.

5.3.4.5 For fine aggregate in transportation units, sampling tubes as described in 5.3.3.3, except inserted vertically, may be used to extract an appropriate number of increments from the trenches to form the field sample.

5.3.5 Sampling from Roadway (Bases and Subbases):

5.3.5.1 Sample units selected by a random method, such as Practice D3665, from the construction.

5.3.5.2 Obtain at least three approximately equal increments, selected at random from the unit being sampled, after the material has been placed and prior to compaction, and combine to form a field sample whose mass equals or exceeds the minimum recommended in 5.4.2. Take all increments from the roadway for the full depth of the material, taking care to exclude any underlying material. Clearly mark the specific areas from which each sample increment is to be removed.

5.3.5.3 A metal template placed over the area will aid in securing approximately equal increment weights. Place the template on top of the material to be sampled. Sample material from the center of the template. As material is extracted from the center of the template, the template is continuously lowered to prevent the material outside of the template from falling into the sample hole. The template shall be composed of metal or other sturdy material, no less than 0.3 m [12 in.] in diameter and 0.25 m [9 in.] in height, providing a sampling area not less than 0.07 m² [110 in.²] (see Fig. 5).

5.4 Number and Masses of Field Samples:

5.4.1 The number of field samples (obtained by one of the methods described in 5.3) required depends on the criticality of, and variation in, the properties to be measured. Designate each unit from which a field sample is to be obtained prior to sampling. The number of field samples from the production shall be sufficient to give the desired confidence in test results.

**FIG. 4 Sampling Fine Aggregate from Stockpile Using Sampling Tube**

**FIG. 5 Proper Use of Metal Template For Sampling Mixed Coarse and Fine Aggregate From Roadway Grade**

NOTE 11—Guidance for determining the number of samples required to obtain the desired level of confidence in test results may be found in Test Method D2234/D2234M, Practice E105, Practice E122, and Practice E141.
5.4.2 The field sample masses cited are tentative. The masses must be predicated on the type and number of tests to which the material is to be subjected and sufficient material obtained to provide for the proper execution of these tests. Standard acceptance and control tests are covered by ASTM standards and specify the portion of the field sample required for each specific test. Generally speaking, the amounts specified in Table 1 will provide adequate material for routine grading and quality analysis. Extract test portions from the field sample according to Practice C702 or as required by other applicable test methods.

6. Shipping Samples

6.1 Transport aggregates in bags or other containers so constructed as to preclude loss or contamination of any part of the sample, or damage to the contents from mishandling during shipment.

6.2 Shipping containers for aggregate samples shall have suitable individual identification attached and enclosed so that field reporting, laboratory logging, and test reporting may be facilitated.

7. Keywords

7.1 aggregates; exploration of potential sources; number and sizes needed to estimate character; sampling

APPENDIXES

(Nonmandatory Information)

X1. EXPLORATION OF POTENTIAL AGGREGATE SOURCES

X1.1 Scope

X1.1.1 Sampling for evaluation of potential aggregate sources should be performed by a responsible trained and experienced person. Because of the wide variety of conditions under which sampling may have to be done it is not possible to describe detailed procedures applicable to all circumstances. This appendix is intended to provide general guidance and list more comprehensive references.

X1.2 Sampling Stone from Quarries or Ledges

X1.2.1 Inspection—The ledge or quarry face should be inspected to determine discernible variations or strata. Differences in color and structure should be recorded.

X1.2.2 Sampling and Size of Sample—Separate samples having a mass of at least 25 kg [55 lbs] should be obtained from each discernible stratum. The sample should not include material weathered to such an extent that it is no longer suitable for the purpose intended. One or more pieces in each sample should be at least 150 by 150 by 100 mm [6 in. by 6 in. by 4 in.] in size with the bedding plane plainly marked, and this piece should be free of seams or fractures.

X1.2.3 Record—In addition to the general information accompanying all samples the following information should accompany samples taken from ledges or quarry faces:

X1.2.3.1 Approximate quantity available. (If quantity is very large this may be recorded as practically unlimited.)

X1.2.3.2 Quantity and character of overburden.

X1.2.3.3 A detailed record showing boundaries and location of material represented by each sample.

NOTE X1.1—A sketch, plan, and elevation, showing the thickness and

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TABLE 1 Minimum Size of Field Samples

<table>
<thead>
<tr>
<th>Aggregate Size</th>
<th>Field Sample Mass, min, kg[a]</th>
<th>Field Sample Volume, min, L [gal]</th>
</tr>
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<tbody>
<tr>
<td>Fine Aggregate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.36 mm [No. 8]</td>
<td>10 [22]</td>
<td>8 [2]</td>
</tr>
<tr>
<td>4.75 mm [No. 4]</td>
<td>10 [22]</td>
<td>8 [2]</td>
</tr>
<tr>
<td>Coarse Aggregate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.5 mm [⅓ in.]</td>
<td>10 [22]</td>
<td>8 [2]</td>
</tr>
<tr>
<td>12.5 mm [½ in.]</td>
<td>15 [35]</td>
<td>12 [3]</td>
</tr>
<tr>
<td>25.0 mm [1 in.]</td>
<td>50 [110]</td>
<td>40 [10]</td>
</tr>
<tr>
<td>37.5 mm [⅞ in.]</td>
<td>75 [165]</td>
<td>60 [15]</td>
</tr>
<tr>
<td>50 mm [2 in.]</td>
<td>100 [220]</td>
<td>80 [21]</td>
</tr>
<tr>
<td>63 mm [2⅞ in.]</td>
<td>125 [275]</td>
<td>100 [26]</td>
</tr>
<tr>
<td>75 mm [3 in.]</td>
<td>150 [330]</td>
<td>120 [32]</td>
</tr>
<tr>
<td>90 mm [3⅜ in.]</td>
<td>175 [385]</td>
<td>140 [37]</td>
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[a] For processed aggregates, use the nominal maximum size as indicated by the appropriate specification or description. If the specification or description does not indicate a nominal maximum size (for example, a sieve size indicating 90 to 100 % passing), use the maximum size (that sieve indicating 100 % passing).

[b] For combined coarse and fine aggregates (for example, base or subbase aggregate), the minimum weight shall be coarse aggregate minimum mass plus 10 kg.
X1.3 Sampling Roadside or Bank Run Sand and Gravel Deposits

X1.3.1 Inspection—Potential sources of bank run sand and gravel may include previously worked pits from which there is an exposed face or potential deposits discovered through air-photo interpretation, geophysical exploration, or other types of terrain investigation.

X1.3.2 Sampling—Samples should be so chosen from each different stratum in the deposit discernible to the sampler. An estimate of the quantity of the different materials should be made. If the deposit is worked as an open-face bank or pit, samples should be taken by channeling the face vertically, bottom to top, so as to represent the materials proposed for use. Overburdened or disturbed material should not be included in the sample. Test holes should be excavated or drilled at numerous locations in the deposit to determine the quality of the material and the extent of the deposit beyond the exposed face, if any. The number and depth of test holes will depend upon the quantity of the material needed, topography of the area, nature of the deposit, character of the material, and potential value of the material in the deposit. If visual inspection indicates that there is considerable variation in the material, individual samples should be selected from the material in each well defined stratum. Each sample should be thoroughly mixed and quartered if necessary so that the field sample thus obtained will be at least 12 kg [25 lbs] for sand and 35 kg [75 lbs] if the deposit contains an appreciable amount of coarse aggregate.

X1.3.3 Record—In addition to the general information accompanying all samples the following information should accompany samples of bank run sand and gravel:

X1.3.3.1 Location of supply.
X1.3.3.2 Estimate of approximate quantity available.
X1.3.3.3 Quantity and character of overburden.
X1.3.3.4 Length of haul to proposed site of work.
X1.3.3.5 Character of haul (kind of road, maximum grades, and so forth)
X1.3.3.6 Details as to extent and location of material represented by each sample.

Note X1.2—A sketch of plans and elevations, showing the thickness and location of different layers, is recommended for this purpose.

X2. NUMBER AND SIZE OF INCREMENTS NEEDED TO ESTIMATE CHARACTER OF UNIT SAMPLED

X2.1 Scope

X2.1.1 This appendix presents the rationale used by the responsible committee in the development of this practice.

X2.2 Descriptions of Terms Specific to This Standard

X2.2.1 field sample—a quantity of the material of sufficient size to provide an acceptable estimate of the average quality of a unit.

X2.2.2 lot—a sizable isolated quantity of bulk material from a single source, assumed to have been produced by the same process (for example, a day’s production or a specific mass or volume).

X2.2.3 test portion—a quantity of the material to be tested of sufficient size extracted from the larger field sample by a procedure designed to ensure accurate representation of the field sample, and thus of the unit sampled.

X2.2.4 unit—a batch or finite subdivision of a lot of bulk material (for example, a truck load or a specific area covered).

X2.3 Test Unit, Size, and Variability

X2.3.1 The unit to be represented by a single field sample should neither be so large as to mask the effects of significant variability within the unit nor be so small as to be affected by the inherent variability between small portions of any bulk material.

X2.3.2 A unit of bulk material composed of graded aggregate or aggregate mixtures might consist of a full truckload. If it were possible, the entire load might be tested; as a practical matter, a field sample is composed of three or more increments chosen at random from the material as it is loaded or unloaded from the truck. Research has shown that such a procedure permits an acceptable estimate to be made of the average gradation that might be measured from 15 or 20 increments from the truck.

X2.3.3 Significant variability with a lot of material, where it might exist, should be indicated by statistical measures, such as the standard deviation between units selected at random from within the lot.
Standard Method of Test for

Materials Finer Than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing

AASHTO Designation: T 11-05 (2018)¹

Technical Section: 1c, Aggregates

Release: Group 3 (August)

ASTM Designation: C117-13
1. SCOPE

1.1. This test method covers determination of the amount of material finer than a 75-µm (No. 200) sieve in aggregate by washing. Clay particles and other aggregate particles that are dispersed by the wash water, as well as water-soluble materials, will be removed from the aggregate during the test.

1.2. Two procedures are included, one using only water for the washing operation, and the other including a wetting agent to assist the loosening of the material finer than the 75-µm (No. 200) sieve from the coarser material. Unless otherwise specified, Procedure A (water only) shall be used.

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

1.4. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to its use.

2. REFERENCED DOCUMENTS

2.1. AASHTO Standards:
- M 231, Weighing Devices Used in the Testing of Materials
- R 76, Reducing Samples of Aggregate to Testing Size
- R 90, Sampling Aggregate Products
- T 27, Sieve Analysis of Fine and Coarse Aggregates

2.2. ASTM Standards:
- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- E11, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves
3. SUMMARY OF METHOD

3.1. A sample of the aggregate is washed in a prescribed manner, using either plain water or water containing a wetting agent, as specified. The decanted wash water, containing suspended and dissolved material, is passed through a 75-µm (No. 200) sieve. The loss in mass resulting from the wash treatment is calculated as mass percent of the original sample and is reported as the percentage of material finer than a 75-µm (No. 200) sieve by washing.

4. SIGNIFICANCE AND USE

4.1. Material finer than the 75-µm (No. 200) sieve can be separated from larger particles much more efficiently and completely by wet sieving than through the use of dry sieving. Therefore, when accurate determinations of material finer than 75 µm in fine or coarse aggregate are desired, this test method is used on the sample prior to dry sieving in accordance with T 27. The results of this test method are included in the calculation in T 27, and the total amount of material finer than 75 µm by washing, plus that obtained by dry sieving the same sample, is reported with the results of T 27. Usually the additional amount of material finer than 75 µm obtained in the dry-sieving process is a small amount. If it is large, the efficiency of the washing operation should be checked. A large amount of material could also be an indication of the degradation of the aggregate.

4.2. Plain water is adequate to separate the material finer than 75 µm from the coarser material in most aggregates. In some cases, the finer material is adhered to the larger particles, such as in some clay coatings and coatings on aggregates that have been extracted from bituminous mixtures. In these cases, the fine material will be separated more readily with a wetting agent in the water.

5. APPARATUS AND MATERIALS

5.1. 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.

5.2. Sieves—A nest of two sieves, the lower being a 75-µm (No. 200) sieve and the upper being a sieve with openings in the range of 2.36 mm (No. 8) to 1.18 mm (No. 16), both conforming to the requirement of ASTM E11.

5.3. Container—A pan or vessel of a size sufficient to contain the sample covered with water and to permit vigorous agitation without loss of any part of the sample or water.

5.4. Oven—An oven of sufficient size, capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F).

5.5. Wetting Agent—Any dispersing agent, such as liquid dishwashing detergents, that will promote separation of the fine materials.

Note 1—The use of a mechanical apparatus to perform the washing operation is not precluded, provided the results are consistent with those obtained using manual operations. The use of some mechanical washing equipment with some samples may cause degradation of the sample.

6. SAMPLING

6.1. Sample the aggregate in accordance with R 90. If the same test sample is to be tested for sieve analysis according to T 27, comply with the applicable requirements of that method.
6.2. Thoroughly mix the sample of aggregate to be tested and reduce the quantity to an amount suitable for testing using the applicable methods described in R 76. If the same test sample is to be tested according to T 27, the minimum mass shall be as described in the applicable sections of that method. Otherwise, the mass of the test sample, after drying, shall conform with the following:

<table>
<thead>
<tr>
<th>Nominal Maximum Size</th>
<th>Minimum Mass, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75 mm (No. 4) or smaller</td>
<td>300</td>
</tr>
<tr>
<td>9.5 mm (3/8 in.)</td>
<td>1000</td>
</tr>
<tr>
<td>19.0 mm (3/4 in.)</td>
<td>2500</td>
</tr>
<tr>
<td>37.5 mm (1/2 in.) or larger</td>
<td>5000</td>
</tr>
</tbody>
</table>

The test sample shall be the end result of the reduction. Reduction to an exact predetermined mass shall not be permitted. If the nominal maximum size of the aggregate to be tested is not listed above, the next larger size listed shall be used to determine sample size.

7. SELECTION OF PROCEDURE

7.1. Procedure A shall be used, unless otherwise specified by the specification with which the test results are to be compared, or when directed by the agency for which the work is performed.

8. PROCEDURE A—WASHING WITH PLAIN WATER

8.1. Dry the test sample to constant mass at a temperature of 110 ± 5°C (230 ± 9°F). Determine the mass to the nearest 0.1 percent of the mass of the test sample.

8.2. If the applicable specification requires that the amount passing the 75-µm (No. 200) sieve shall be determined on a portion of the sample passing a sieve smaller than the nominal maximum size of the aggregate, separate the sample on the designated sieve and determine the mass of the material passing the designated sieve to 0.1 percent of the mass of this portion of the test sample. Use this mass as the original dry mass of the test sample in Section 10.1.

Note 2—Some specifications for aggregates with a nominal maximum size of 50 mm or greater, for example, provide a limit for material passing the 75-µm (No. 200) sieve determined on that portion of the sample passing the 25.0-mm sieve. Such procedures are necessary because it is impractical to wash samples of the size required when the same test sample is to be used for sieve analysis by T 27.

8.3. After drying and determining the mass, place the test sample in the container and add sufficient water to cover it. No detergent, dispersing agent, or other substance shall be added to the water. Agitate the sample with sufficient vigor to result in complete separation of all particles finer than the 75-µm (No. 200) sieve from the coarser particles, and to bring the fine material into suspension. The use of a large spoon or other similar tool to stir and agitate the aggregate in the wash water has been found satisfactory. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, arranged with the coarser sieve on top. Take care to avoid, as much as feasible, the decantation of coarser particles of the sample.

8.4. Add a second charge of water to the sample in the container, agitate, and decant as before. Repeat this operation until the wash water is clear.

Note 3—If mechanical washing equipment is used, the charging of water, agitating, and decanting may be a continuous operation.

Note 4—A spray nozzle or a piece of rubber tubing attached to a water faucet may be used to rinse any of the material that may have fallen onto the sieves. The velocity of water, which may be
increased by pinching the tubing or by use of a nozzle, should not be sufficient to cause any splashing of the sample over the sides of the sieve.

8.5. Return all material retained on the nested sieves by flushing into the container containing the washed sample. Dry the washed aggregate to constant mass at a temperature of 110 ± 5°C (230 ± 9°F) and determine the mass to the nearest 0.1 percent of the original mass of the sample.

Note 5—Following the washing of the sample and flushing any materials retained on the 75-µm (No. 200) sieve back into the container, no water should be decanted from the container except through the 75-µm sieve, to avoid loss of material. Excess water from flushing should be evaporated from the sample in the drying process.

9. **PROCEDURE B—WASHING USING A WETTING AGENT**

9.1. Prepare the sample in the same manner as for Procedure A.

9.2. After drying and determining the mass, place the test sample in the container. Add sufficient water to cover the sample, and add wetting agent to the water (Note 6). Agitate the sample with sufficient vigor to result in complete separation of all particles finer than the 75-µm (No. 200) sieve from the coarser particles, and to bring the fine material into suspension. The use of a large spoon or other similar tool to stir and agitate the aggregate in the wash water has been found satisfactory. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, arranged with the coarser sieve on top. Take care to avoid, as much as feasible, the decantation of coarser particles of the sample.

Note 6—There should be enough wetting agent to produce a small amount of suds when the sample is agitated. The quantity will depend on the hardness of the water and the quality of the detergent. Excessive suds may overflow the sieves and carry some material with them.

9.3. Add a second charge of water (without wetting agent) to the sample in the container, agitate, and decant as before. Repeat this operation until the wash water is clear.

9.4. Complete the test as for Procedure A.

10. **CALCULATION**

10.1. Calculate the amount of material passing a 75-µm (No. 200) sieve by washing as follows:

\[
A = \left[ \frac{(B - C)}{B} \right] \times 100 \tag{1}
\]

where:

\[ A \] = percentage of material finer than a 75-µm (No. 200) sieve by washing;

\[ B \] = original dry mass of sample, g; and

\[ C \] = dry mass of sample after washing, g.

11. **REPORT**

11.1. Report the percentage of material finer than the 75-µm (No. 200) sieve by washing to the nearest 0.1 percent, except if the result is 10 percent or more, report the percentage to the nearest whole number.

11.2. Include a statement as to which procedure was used.
12. PRECISION AND BIAS

12.1. Precision—The estimates of precision of this test method listed in Table 1 are based on results from the AASHTO Materials Reference Laboratory Proficiency Sample Program, with testing conducted by this test method and ASTM C117. The significant differences between the methods at the time the data were acquired is that T 11 required, and ASTM C117 prohibited, the use of a wetting agent. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories.

Table 1—Precision

<table>
<thead>
<tr>
<th></th>
<th>Standard Deviation (1σ, %)</th>
<th>Acceptable Range of Two Results (d2σ, %)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coarse aggregate:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-operator precision</td>
<td>0.10</td>
<td>0.28</td>
</tr>
<tr>
<td>Multilaboratory precision</td>
<td>0.22</td>
<td>0.62</td>
</tr>
<tr>
<td><strong>Fine aggregate:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-operator precision</td>
<td>0.15</td>
<td>0.43</td>
</tr>
<tr>
<td>Multilaboratory precision</td>
<td>0.29</td>
<td>0.82</td>
</tr>
</tbody>
</table>

These numbers represent the (1σ) and (d2σ) limits as described in ASTM C670.

Precision estimates are based on aggregates having a nominal maximum size of 19.0 mm (3/4 in.) with less than 1.5 percent finer than the 75-μm (No. 200) sieve.

Precision estimates are based on fine aggregates having 1.0 to 3.0 percent finer than the 75-μm (No. 200) sieve.

12.1.1. The precision values for fine aggregate in Table 1 are based on nominal 500-g test samples. Revision of this test method in 1996 permits the fine aggregate test sample size to be 300 g minimum. Analysis of results of testing of 300-g and 500-g test samples from Aggregate Proficiency Test Samples 99 and 100 (Samples 99 and 100 were essentially identical) produced the precision values in Table 2, which indicates only minor differences due to test sample size.

Table 2—Precision Data for 300-g and 500-g Test Samples

<table>
<thead>
<tr>
<th>Test Result</th>
<th>Sample Size</th>
<th>No. Labs</th>
<th>Avg</th>
<th>1σ</th>
<th>d2σ</th>
<th>1σ</th>
<th>d2σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>AASHTO T 11/ASTM C117 (Total material passing the No. 200 sieve by washing, %)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500 g</td>
<td>270</td>
<td>1.23</td>
<td>0.08</td>
<td>0.24</td>
<td>0.23</td>
<td>0.66</td>
<td></td>
</tr>
<tr>
<td>300 g</td>
<td>264</td>
<td>1.20</td>
<td>0.10</td>
<td>0.29</td>
<td>0.24</td>
<td>0.68</td>
<td></td>
</tr>
</tbody>
</table>

Note 7—The values for fine aggregate in Table 1 will be revised to reflect the 300-g test sample size when a sufficient number of Aggregate Proficiency Tests have been conducted using that sample size to provide reliable data.

12.2. Bias—Because there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is made.

13. KEYWORDS

13.1. Aggregate; size analysis; wash loss; 75-μm (No. 200) sieve.

1 Except for Sections 5.1 and 6.2, and Note 4, this test method is identical to ASTM C117-13.
Standard Method of Test for

Sieve Analysis of Fine and Coarse Aggregates

AASHTO Designation: T 27-14 (2018)¹
Technical Section: 1c, Aggregates
Release: Group 3 (August)
ASTM Designation: C136-06
1. SCOPE

1.1. This method covers the determination of the particle size distribution of fine and coarse aggregates by sieving.

1.2. Some specifications for aggregates, which reference this method, contain grading requirements including both coarse and fine fractions. Instructions are included for sieve analysis of such aggregates.

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

1.4. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this procedure to consult and establish appropriate safety and health practices and to determine the applicability of regulatory regulations prior to its use.

2. REFERENCED DOCUMENTS

2.1. AASHTO Standards:
   - M 231, Weighing Devices Used in the Testing of Materials
   - R 76, Reducing Samples of Aggregate to Testing Size
   - R 90, Sampling Aggregate Products
   - T 11, Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

2.2. ASTM Standards:
   - C125, Standard Terminology Relating to Concrete and Concrete Aggregates
   - C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
   - E11, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves

2.3. IEEE/ASTM Standard:
   - SI 10, American National Standard for Metric Practice
3. TERMINOLOGY

3.1. Definitions—For definitions of terms used in this standard, refer to ASTM C125.

4. SUMMARY OF METHOD

4.1. A sample of dry aggregate of known mass is separated through a series of sieves of progressively smaller openings for determination of particle size distribution.

5. SIGNIFICANCE AND USE

5.1. This method is used primarily to determine the grading of materials proposed for use as aggregates or being used as aggregates. The results are used to determine compliance of the particle size distribution with applicable specification requirements and to provide necessary data for control of the production of various aggregate products and mixtures containing aggregates. The data may also be useful in developing relationships concerning porosity and packing.

5.2. Accurate determination of material finer than the 75-µm (No. 200) sieve cannot be achieved by use of this method alone. T 11 for material finer than the 75-µm (No. 200) sieve by washing should be employed.

6. APPARATUS

6.1. 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.

6.2. Sieves—The sieve cloth shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sieving. The sieve cloth and standard sieve frames shall conform to the requirements of ASTM E11. Nonstandard sieve frames shall conform to the requirements of ASTM E11 as applicable.

Note 1—It is recommended that sieves mounted in frames larger than standard 203.2 mm (8 in.) diameter be used for testing coarse aggregate to reduce the possibility of overloading the sieves. See Section 8.3.

6.3. Mechanical Sieve Shaker—A mechanical sieving device, if used, shall create motion of the sieves to cause the particles to bounce, tumble, or otherwise turn so as to present different orientations to the sieving surface. The sieving action shall be such that the criterion for adequacy of sieving described in Section 8.4 is met in a reasonable time period.

Note 2—Use of a mechanical sieve shaker is recommended when the size of the sample is 20 kg (44 lb) or greater, and may be used for smaller samples, including fine aggregate. Excessive time (more than approximately 10 min) to achieve adequate sieving may result in degradation of the sample. The same mechanical sieve shaker may not be practical for all sizes of samples because the large sieving area needed for practical sieving of a large nominal size coarse aggregate very likely could result in loss of a portion of the sample if used for a smaller sample of coarse aggregate or fine aggregate.

6.4. Oven—An oven of appropriate size capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F).
7. **SAMPLING**

7.1. Sample the aggregate in accordance with R 90. The mass of the field sample shall be the mass shown in R 90 or four times the mass required in Sections 7.4 and 7.5 (except as modified in Section 7.6), whichever is greater.

7.2. Thoroughly mix the sample and reduce it to an amount suitable for testing using the applicable procedures described in R 76. The sample for test shall be the approximate mass desired when dry and shall be the end result of the reduction. Reduction to an exact predetermined mass shall not be permitted.

**Note 3**—Where sieve analysis, including determination of material finer than the 75-µm (No. 200) sieve, is the only testing proposed, the size of the sample may be reduced in the field to avoid shipping excessive quantities of extra material to the laboratory.

7.3. **Fine Aggregate**—The size of the test sample of aggregate, after drying, shall be 300 g minimum.

7.4. **Coarse Aggregate**—The mass of the test sample of coarse aggregate shall conform with the following:

<table>
<thead>
<tr>
<th>Nominal Maximum Size Square Openings, mm (in.)</th>
<th>Minimum Mass of Test Sample, kg (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.5 (1/4)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>12.5 (1/2)</td>
<td>2 (4)</td>
</tr>
<tr>
<td>19.0 (3/4)</td>
<td>5 (11)</td>
</tr>
<tr>
<td>25.0 (1)</td>
<td>10 (22)</td>
</tr>
<tr>
<td>37.5 (1 1/2)</td>
<td>15 (33)</td>
</tr>
<tr>
<td>50 (2)</td>
<td>20 (44)</td>
</tr>
<tr>
<td>63 (2 1/2)</td>
<td>35 (77)</td>
</tr>
<tr>
<td>75 (3)</td>
<td>60 (130)</td>
</tr>
<tr>
<td>90 (3 1/2)</td>
<td>100 (220)</td>
</tr>
<tr>
<td>100 (4)</td>
<td>150 (330)</td>
</tr>
<tr>
<td>125 (5)</td>
<td>300 (660)</td>
</tr>
</tbody>
</table>

7.5. **Coarse and Fine Aggregates Mixtures**—The mass of the test sample of coarse and fine aggregate mixtures shall be the same as for coarse aggregate in Section 7.4.

7.6. **Samples of Large-Size Coarse Aggregate**—The size of sample required for aggregate with 50-mm (2-in.) nominal maximum size or larger is such as to preclude convenient sample reduction and testing as a unit except with large mechanical splitters and sieve shakers. As an option when such equipment is not available, instead of combining and mixing sample increments and then reducing the field sample to testing size, conduct the sieve analysis on a number of approximately equal sample increments such that the total mass tested conforms to the requirements of Section 7.4.

7.7. In the event that the amount of material finer than the 75-µm (No. 200) sieve is to be determined by T 11, use the procedure described in Section 7.7.1 or 7.7.2, whichever is applicable.

7.7.1. For aggregates with a nominal maximum size of 12.5 mm (1/2 in.) or less, use the same test sample for testing by T 11 and this method. First test the sample in accordance with T 11 through the final drying operation, then dry sieve the sample as stipulated in Sections 8.2 through 8.6 of this method.
7.7.2. For aggregates with a nominal maximum size greater than 12.5 mm (1/2 in.), a single test sample may be used as described in Section 7.7.1 or separate test samples may be used for T 11 and this method.

7.7.3. Where the specification requires determination of the total amount of material finer than the 75-µm (No. 200) sieve by washing and dry sieving, use the procedure described in Section 7.7.1.

8. PROCEDURE

8.1. If the test sample has not been subjected to testing by T 11, dry it to constant mass at a temperature of 110 ± 5°C (230 ± 9°F). Determine and record the mass of material that will be placed on the sieves to the accuracy of the balance as defined in Section 6.1.

Note 4—For control purposes, particularly where rapid results are desired, it is generally not necessary to dry coarse aggregate for the sieve analysis test. The results are little affected by the moisture content unless (1) the nominal maximum size is smaller than about 12.5 mm (1/2 in.), (2) the coarse aggregate contains appreciable material finer than 4.75 mm (No. 4), or (3) the coarse aggregate is highly absorptive (a lightweight aggregate, for example). Also, samples may be dried at the higher temperature associated with the use of hot plates without affecting results, provided steam escapes without generating pressures sufficient to fracture the particles, and temperatures are not so great as to cause chemical breakdown of the aggregate.

8.2. Select sieves with suitable openings to furnish the information required by the specifications covering the material to be tested. Use additional sieves as desired or necessary to provide other information, such as fineness modulus, or to regulate the amount of material on a sieve. Nest the sieves in order of decreasing size of opening from top to bottom and place the sample, or portion of the sample if it is to be sieved in more than one increment, on the top sieve. Agitate the sieves by hand or by mechanical apparatus for a sufficient period, established by trial or checked by measurement on the actual test sample, to meet the criterion for adequacy of sieving described in Section 8.4.

8.3. Limit the quantity of material on a given sieve so that all particles have opportunity to reach sieve openings a number of times during the sieving operation. For sieves with openings smaller than 4.75-mm (No. 4), the quantity retained on any sieve at the completion of the sieving operation shall not exceed 7 kg/m² (4 g/in.²) of sieving surface area (Note 5). For sieves with openings 4.75 mm (No. 4) and larger, the quantity retained in kg shall not exceed the product of 2.5 × (sieve opening, mm × (effective sieving area, m²)). This quantity is shown in Table 1 for five sieve-frame dimensions in common use. In no case shall the quantity retained be so great as to cause permanent deformation of the sieve cloth.

8.3.1. Prevent an overload of material on an individual sieve by one or a combination of the following methods:

8.3.1.1. Insert an additional sieve with opening size intermediate between the sieve that may be overloaded and the sieve immediately above that sieve in the original set of sieves.

8.3.1.2. Split the sample into two or more portions, sieving each portion individually. Combine the masses of the several portions retained on a specific sieve before calculating the percentage of the sample on the sieve.

8.3.1.3. Use sieves having a larger frame size and providing greater sieving area.

Note 5—The 7 kg/m² amounts to 200 g for the usual 203.2-mm (8-in.) diameter sieve (with effective sieving surface diameter of 190.5 mm (7.5 in.)).
8.3.1.4. In the case of coarse and fine aggregate mixtures, the portion of the sample finer than the 4.75-mm (No. 4) sieve may be distributed among two or more sets of sieves to prevent overloading of individual sieves.

8.3.1.5. Alternatively, the portion finer than the 4.75-mm (No. 4) sieve may be reduced in size using a mechanical splitter according to R 76. If this procedure is followed, compute the mass of each size increment of the original sample as follows:

\[ A = \frac{W_1}{W_2} \times B \]  

where:

\( A \) = mass of size increment on total sample basis;
\( W_1 \) = mass of fraction finer than 4.75-mm (No. 4) sieve in total sample;
\( W_2 \) = mass of reduced portion of material finer than 4.75-mm (No. 4) sieve actually sieved; and
\( B \) = mass of size increment in reduced portion sieved.

### Table 1—Maximum Allowable Quantity of Material Retained on a Sieve, kg

<table>
<thead>
<tr>
<th>Sieve Opening Size</th>
<th>Nominal Dimensions of Sieve&lt;sup&gt;a&lt;/sup&gt;</th>
<th>203.2-mm, dia&lt;sup&gt;b&lt;/sup&gt;</th>
<th>254-mm, dia&lt;sup&gt;b&lt;/sup&gt;</th>
<th>304.8-mm, dia&lt;sup&gt;b&lt;/sup&gt;</th>
<th>350 by 350, mm</th>
<th>372 by 580, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Seiving Area, m&lt;sup&gt;2&lt;/sup&gt;</td>
<td>0.0285</td>
<td>0.0457</td>
<td>0.0670</td>
<td>0.1225</td>
<td>0.2158</td>
</tr>
<tr>
<td>125 mm (5 in.)</td>
<td></td>
<td>e</td>
<td>e</td>
<td>e</td>
<td>67.4</td>
<td></td>
</tr>
<tr>
<td>100 mm (4 in.)</td>
<td></td>
<td>e</td>
<td>e</td>
<td>e</td>
<td>30.6</td>
<td>53.9</td>
</tr>
<tr>
<td>90 mm (3 1/2 in.)</td>
<td></td>
<td>e</td>
<td>e</td>
<td>15.1</td>
<td>27.6</td>
<td>48.5</td>
</tr>
<tr>
<td>75 mm (3 in.)</td>
<td></td>
<td>e</td>
<td>8.6</td>
<td>12.6</td>
<td>23.0</td>
<td>40.5</td>
</tr>
<tr>
<td>63 mm (2 1/2 in.)</td>
<td></td>
<td>e</td>
<td>7.2</td>
<td>10.6</td>
<td>19.3</td>
<td>34.0</td>
</tr>
<tr>
<td>50 mm (2 in.)</td>
<td></td>
<td>3.6</td>
<td>5.7</td>
<td>8.4</td>
<td>15.3</td>
<td>27.0</td>
</tr>
<tr>
<td>37.5 mm (1 1/2 in.)</td>
<td></td>
<td>2.7</td>
<td>4.3</td>
<td>6.3</td>
<td>11.5</td>
<td>20.2</td>
</tr>
<tr>
<td>25.0 mm (1 in.)</td>
<td></td>
<td>1.8</td>
<td>2.9</td>
<td>4.2</td>
<td>7.7</td>
<td>13.5</td>
</tr>
<tr>
<td>19.0 mm (1/4 in.)</td>
<td></td>
<td>1.4</td>
<td>2.2</td>
<td>3.2</td>
<td>5.8</td>
<td>10.2</td>
</tr>
<tr>
<td>12.5 mm (1/2 in.)</td>
<td></td>
<td>0.89</td>
<td>1.4</td>
<td>2.1</td>
<td>3.8</td>
<td>6.7</td>
</tr>
<tr>
<td>9.5 mm (1/8 in.)</td>
<td></td>
<td>0.67</td>
<td>1.1</td>
<td>1.6</td>
<td>2.9</td>
<td>5.1</td>
</tr>
<tr>
<td>4.75 mm (No. 4)</td>
<td></td>
<td>0.33</td>
<td>0.54</td>
<td>0.80</td>
<td>1.5</td>
<td>2.6</td>
</tr>
</tbody>
</table>

<sup>a</sup> Sieve frame dimensions in inch units: 8.0-in. diameter; 10.0-in. diameter; 12.0-in. diameter; 13.8 by 13.8 in. (14 by 14 in. nominal); 14.6 by 22.8 in. (16 by 24 in. nominal).

<sup>b</sup> The sieve area for round sieves is based on an effective diameter 12.7 mm (1/2 in.) less than the nominal frame diameter, because ASTM E11 permits the sealer between the sieve cloth and the frame to extend 6.35 mm (1/4 in.) over the sieve cloth. Thus the effective sieving diameter for a 203.2-mm (8-in.) diameter sieve frame is 190.5 mm (7.5 in.). Sieves produced by some manufacturers do not infringe on the sieve cloth by the full 6.35 mm (1/4 in.).

<sup>c</sup> Sieves indicated have less than five full openings and should not be used for sieve testing.

8.4. Continue sieving for a sufficient period and in such manner that, after completion, not more than 0.5 percent by mass of the total sample passes any sieve during 1 min of continuous hand sieving performed as follows: Hold the individual sieve, provided with a snug-fitting pan and cover, in a slightly inclined position in one hand. Strike the side of the sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per minute, turn the sieve about one sixth of a revolution at intervals of about 25 strokes. In determining sufficiency of sieving for sizes larger than the 4.75-mm (No. 4) sieve, limit the material on the sieve to a single layer of particles. If the size of the mounted testing sieves makes the described sieving motion impractical, use 203.2-mm (8-in.) diameter sieves to verify the sufficiency of sieving.
8.5. Unless a mechanical sieve shaker is used, hand sieve particles obtained on the 75 mm (3 in.) by determining the smallest sieve opening through which each particle will pass by rotating the particles, if necessary, in order to determine whether they will pass through a particular opening; however, do not force particles to pass through an opening.

8.6. Determine the mass of each size increment on a scale or balance conforming to the requirements specified in Section 6.1 to the nearest 0.1 percent of the total original dry sample mass. The total mass of the material after sieving should check closely with the total original dry mass of the sample placed on the sieves. If the two amounts differ by more than 0.3 percent, based on the total original dry sample mass, the results should not be used for acceptance purposes.

9. **CALCULATION**

9.1. Calculate percentages passing, total percentages retained, or percentages in various size fractions to the nearest 0.1 percent on the basis of the total mass of the initial dry sample. If the same test sample was first tested by T 11, include the mass of material finer than 75-μm (No. 200) sieve by washing in the sieve analysis calculation; and use the total dry sample mass prior to washing in T 11 as the basis for calculating all the percentages.

9.1.1. When sample increments are tested as provided in Section 7.6, total the masses of the portion of the increments retained on each sieve, and use these masses to calculate the percentage as in Section 9.1.

9.2. Calculate the fineness modulus, when required, by adding the total percentages of material in the sample that are coarser than each of the following sieves (cumulative percentages retained), and dividing the sum by 100; 150 μm (No. 100), 300 μm (No. 50), 600 μm (No. 30), 1.18 mm (No. 16), 2.36 mm (No. 8), 4.75 mm (No. 4), 9.5 mm (3/8 in.), 19.0 mm (3/4 in.), 37.5 mm (1½ in.), and larger, increasing the ratio of 2 to 1.

10. **REPORT**

10.1. *Depending on the form of the specifications for use of the material under test, the report shall include one of the following:*

10.1.1. Total percentage of material passing each sieve, or

10.1.2. Total percentage of material retained on each sieve, or

10.1.3. Percentage of material retained between consecutive sieves.

10.2. Report percentages to the nearest whole number, except if the percentage passing the 75-μm (No. 200) sieve is less than 10 percent, it shall be reported to the nearest 0.1 percent.

10.3. Report the fineness modulus, when required, to the nearest 0.01.

11. **PRECISION AND BIAS**

11.1. *Precision—The estimates of precision for this test method are listed in Table 2. The estimates are based on the results from the AASHTO Materials Reference Laboratory Proficiency Sample Program, with testing conducted by T 27 and ASTM C136. The data are based on the analyses of test results from 65 to 233 laboratories that tested 18 pairs of coarse aggregate proficiency test samples, and test results from 74 to 222 laboratories that tested 17 pairs of fine aggregate*
proficiency test samples (Samples No. 21 through 90). The values in the table are given for different ranges of total percentage of aggregate passing a sieve.

### Table 2—Estimates of Precision

<table>
<thead>
<tr>
<th>Total Percentage of Material Passing</th>
<th>Standard Deviation (1s), a %</th>
<th>Acceptable Range of Two Results (d2s), a %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coarse Aggregate:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-operator precision</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>≥95</td>
<td>0.32</td>
</tr>
<tr>
<td>&lt;95</td>
<td>≥85</td>
<td>0.81</td>
</tr>
<tr>
<td>&lt;85</td>
<td>≥80</td>
<td>1.34</td>
</tr>
<tr>
<td>&lt;80</td>
<td>≥60</td>
<td>2.25</td>
</tr>
<tr>
<td>&lt;60</td>
<td>≥20</td>
<td>1.32</td>
</tr>
<tr>
<td>&lt;20</td>
<td>≥15</td>
<td>0.95</td>
</tr>
<tr>
<td>&lt;15</td>
<td>≥10</td>
<td>1.00</td>
</tr>
<tr>
<td>&lt;10</td>
<td>≥5</td>
<td>0.75</td>
</tr>
<tr>
<td>&lt;5</td>
<td>≥2</td>
<td>0.53</td>
</tr>
<tr>
<td>&lt;2</td>
<td>0</td>
<td>0.27</td>
</tr>
<tr>
<td><strong>Multilaboratory precision</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>≥95</td>
<td>0.35</td>
</tr>
<tr>
<td>&lt;95</td>
<td>≥85</td>
<td>1.37</td>
</tr>
<tr>
<td>&lt;85</td>
<td>≥80</td>
<td>1.92</td>
</tr>
<tr>
<td>&lt;80</td>
<td>≥60</td>
<td>2.82</td>
</tr>
<tr>
<td>&lt;60</td>
<td>≥20</td>
<td>1.97</td>
</tr>
<tr>
<td>&lt;20</td>
<td>≥15</td>
<td>1.60</td>
</tr>
<tr>
<td>&lt;15</td>
<td>≥10</td>
<td>1.48</td>
</tr>
<tr>
<td>&lt;10</td>
<td>≥5</td>
<td>1.22</td>
</tr>
<tr>
<td>&lt;5</td>
<td>≥2</td>
<td>1.04</td>
</tr>
<tr>
<td>&lt;2</td>
<td>0</td>
<td>0.45</td>
</tr>
<tr>
<td><strong>Fine Aggregate:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-operator precision</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>≥95</td>
<td>0.26</td>
</tr>
<tr>
<td>&lt;95</td>
<td>≥60</td>
<td>0.55</td>
</tr>
<tr>
<td>&lt;60</td>
<td>≥20</td>
<td>0.83</td>
</tr>
<tr>
<td>&lt;20</td>
<td>≥15</td>
<td>0.54</td>
</tr>
<tr>
<td>&lt;15</td>
<td>≥10</td>
<td>0.36</td>
</tr>
<tr>
<td>&lt;10</td>
<td>≥2</td>
<td>0.37</td>
</tr>
<tr>
<td>&lt;2</td>
<td>0</td>
<td>0.14</td>
</tr>
<tr>
<td><strong>Multilaboratory precision</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>≥95</td>
<td>0.23</td>
</tr>
<tr>
<td>&lt;95</td>
<td>≥60</td>
<td>0.77</td>
</tr>
<tr>
<td>&lt;60</td>
<td>≥20</td>
<td>1.41</td>
</tr>
<tr>
<td>&lt;20</td>
<td>≥15</td>
<td>1.10</td>
</tr>
<tr>
<td>&lt;15</td>
<td>≥10</td>
<td>0.73</td>
</tr>
<tr>
<td>&lt;10</td>
<td>≥2</td>
<td>0.65</td>
</tr>
<tr>
<td>&lt;2</td>
<td>0</td>
<td>0.31</td>
</tr>
</tbody>
</table>

*a* These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM C670.

*b* The precision estimates are based on aggregates with nominal maximum size of 19.0 mm (3/4 in.).

11.1.1. The precision values for Fine Aggregate in Table 2 are based on nominal 500-g test samples. Revision of ASTM C136 in 1994 permitted the fine aggregate test sample size to be 300 g minimum. Analysis of results of testing of 300-g and 500-g test samples from Aggregate Proficiency Test Samples 99 and 100 (Samples 99 and 100 were essentially identical) produced the precision values in Table 3, which indicate only minor differences due to test sample size.

**Note 6**—The values for Fine Aggregate in Table 2 will be revised to reflect the 300-g test sample size when a sufficient number of Aggregate Proficiency Tests have been conducted using that sample size to provide reliable data.
### Table 3—Precision Data for 300-g and 500-g Fine Aggregate Test Samples

<table>
<thead>
<tr>
<th>Fine Aggregate Proficiency Sample</th>
<th>Sample Size</th>
<th>Number of Labs</th>
<th>Average</th>
<th>Within Laboratory</th>
<th>Among Laboratories</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1s</td>
<td>d2s</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1s</td>
<td>d2s</td>
</tr>
<tr>
<td>AASHTO T 27/ASTM C136:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total material passing the 4.75-mm (No. 4) sieve (%)</td>
<td>500 g</td>
<td>285</td>
<td>99.992</td>
<td>0.027</td>
<td>0.066</td>
</tr>
<tr>
<td></td>
<td>300 g</td>
<td>276</td>
<td>99.990</td>
<td>0.021</td>
<td>0.060</td>
</tr>
<tr>
<td>Total material passing the 2.36-mm (No. 8) sieve (%)</td>
<td>500 g</td>
<td>281</td>
<td>84.10</td>
<td>0.43</td>
<td>1.21</td>
</tr>
<tr>
<td></td>
<td>300 g</td>
<td>274</td>
<td>84.32</td>
<td>0.39</td>
<td>1.09</td>
</tr>
<tr>
<td>Total material passing the 1.18-mm (No. 16) sieve (%)</td>
<td>500 g</td>
<td>286</td>
<td>70.11</td>
<td>0.53</td>
<td>1.49</td>
</tr>
<tr>
<td></td>
<td>300 g</td>
<td>272</td>
<td>70.00</td>
<td>0.62</td>
<td>1.74</td>
</tr>
<tr>
<td>Total material passing the 600-μm (No. 30) sieve (%)</td>
<td>500 g</td>
<td>287</td>
<td>48.54</td>
<td>0.75</td>
<td>2.10</td>
</tr>
<tr>
<td></td>
<td>300 g</td>
<td>276</td>
<td>48.44</td>
<td>0.87</td>
<td>2.44</td>
</tr>
<tr>
<td>Total material passing the 300-μm (No. 50) sieve (%)</td>
<td>500 g</td>
<td>286</td>
<td>13.52</td>
<td>0.42</td>
<td>1.17</td>
</tr>
<tr>
<td></td>
<td>300 g</td>
<td>275</td>
<td>13.51</td>
<td>0.45</td>
<td>1.25</td>
</tr>
<tr>
<td>Total material passing the 150-μm (No. 100) sieve (%)</td>
<td>500 g</td>
<td>287</td>
<td>2.55</td>
<td>0.15</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>300 g</td>
<td>270</td>
<td>2.52</td>
<td>0.18</td>
<td>0.52</td>
</tr>
<tr>
<td>Total material passing the 75-μm (No. 200) sieve (%)</td>
<td>500 g</td>
<td>278</td>
<td>1.32</td>
<td>0.11</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>300 g</td>
<td>266</td>
<td>1.30</td>
<td>0.14</td>
<td>0.39</td>
</tr>
</tbody>
</table>

11.2. **Bias**—Because there is no accepted reference material suitable for determining the bias in this test method, no statement on bias is made.

### 12. KEYWORDS

12.1. Aggregate gradation; fineness modulus.

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1 Similar but not identical to ASTM C136-06.
Standard Method of Test for

Mechanical Analysis of Extracted Aggregate

AASHTO Designation: T 30-15
Technical Section: 2c, Asphalt–Aggregate Mixtures
Release: Group 3 (August)
1. SCOPE

1.1. This method covers a procedure for the determination of the particle-size distribution of fine and coarse aggregates extracted from asphalt mixtures using sieves with square openings.

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

2. REFERENCED DOCUMENTS

2.1. AASHTO Standards:

- M 231, Weighing Devices Used in the Testing of Materials
- R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
- R 35, Superpave Volumetric Design for Asphalt Mixtures
- R 61, Establishing Requirements for Equipment Calibrations, Standardizations, and Checks
- T 164, Quantitative Extraction of Asphalt Binder from Hot Mix Asphalt (HMA)
- T 255, Total Evaporable Moisture Content of Aggregate by Drying
- T 308, Determining the Asphalt Binder Content of Asphalt Mixtures by the Ignition Method

2.2. ASTM Standards:

- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- E11, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. SIGNIFICANCE AND USE

3.1. This method is used to determine the grading of aggregates extracted from asphalt mixtures. The results are used to determine compliance of the particle-size distribution with applicable requirements and to provide necessary data for control of the production of various aggregates to be used in asphalt mixtures.

4. APPARATUS

4.1. Balance—A Class G2 balance meeting the accuracy requirements of M 231.

4.2. Sieves—Conforming to the requirements of ASTM E11.
4.3. **Mechanical Sieve Shaker**—A mechanical sieving device, if used, shall continually reorient the particles on the sieving surface. The sieving action shall meet the requirements for sieving adequacy described in Section 7 in a reasonable time period (Note 1).

**Note 1**—Use of a mechanical sieve shaker is recommended when the size of the sample is 20 kg (44 lb) or greater, and may be used for smaller samples, including fine aggregate. Excessive time (more than 10 min) to achieve adequate sieving may result in degradation of the sample. The same mechanical sieve shaker may not be practical for all sizes of samples, because a large sieving area is needed for practical sieving of a large nominal size coarse aggregate. Use of the same device for a smaller size of coarse aggregate or fine aggregate will likely result in loss of a portion of the sample.

4.4. **Oven**—An oven of sufficient size, capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F).

4.5. **Wetting Agent**—Any dispersing agent, such as dishwashing detergent, that will promote separation of the fine materials.

4.6. **Container**—A pan or vessel of a size sufficient to contain the sample covered with water and to permit vigorous agitation without loss of any part of the sample or water.

4.7. **Spoon or Mixing Utensil**—Or similar device for agitating the sample during the washing procedure.

4.8. **Mechanical Washing Apparatus (Optional)**—See Note 2.

**Note 2**—The use of some mechanical washing equipment with certain material types may cause degradation of the sample, impacting the results of the particle size analysis. To determine if a particular mechanical washing apparatus causes significant degradation, prepare a known aggregate blend gradation in the laboratory using washed and graded aggregate from individual aggregate stockpiles similarly to preparing an aggregate trial blend gradation as specified in R 35. Mechanically wash and then grade the prepared aggregate blend sample. Compare the mechanically washed grading results to the known gradation of the laboratory-prepared aggregate blend for each sieve size. If the determined percentage passing each sieve for mechanical washing differs by more than the acceptable range of two results between laboratories given in Table 2, the mechanical washing apparatus should not be used.

5. **CALIBRATIONS, STANDARDIZATIONS, AND CHECKS**

5.1. Unless otherwise specified, follow the requirements and intervals for equipment calibrations, standardizations, and checks found in R 18.

5.2. Follow the procedures for performing equipment calibration, standardizations, and checks found in R 61.

6. **SAMPLE**

6.1. The sample shall consist of the entire lot or representative sample of aggregate obtained according to T 164 or T 308 from which the binder material has been extracted.
7. PROCEDURE

7.1. Dry the sample, if necessary, until further drying at 110 ± 5°C (230 ± 9°F) does not alter the mass by more than 0.1 percent (Note 3). Determine and record the mass of the sample to the nearest 0.1 g.

Note 3—Samples obtained from T 164 or T 308 should be dried to constant mass as part of the procedures within those standards. If the procedures described herein are completed immediately following the procedures in either of those methods, it will not be necessary to dry the sample again. If more than 24 h pass between the completion of T 164 or T 308 and the beginning of this test procedure, or if the sample is stored in a high-humidity environment, or has otherwise been subjected to moisture, the sample should be dried again to constant mass.

7.1.1. If the sample consists of aggregate obtained from T 164, add the mass of mineral matter contained in the extracted asphalt binder to the mass of the dry sample and record this value as the initial specimen mass (Note 4). The procedure for determination of the mineral matter content of the extracted asphalt is described in T 164.

Note 4—If the asphalt mixture was extracted in accordance with T 164, Method E, for plant control purposes, a mineral matter determination may not have been completed. In this case, record the mass determined in Section 7.1 as the initial specimen mass.

7.1.2. If the sample consists of aggregate obtained from T 308, the mass determined in Section 7.1 shall agree with the mass of aggregate remaining after ignition (Mf from T 308) within 0.1 percent. If the variation exceeds 0.1 percent, the results of this test should not be used for acceptance purposes. Record the mass determined in Section 7.1 as the initial specimen mass.

7.2. Place the test sample in a container and cover it with water. Add a sufficient amount of wetting agent to assure a thorough separation of the material finer than the 75-µm (No. 200) sieve from the coarser particles. Add the wetting agent (Note 5). Agitate the contents of the container vigorously and immediately decant the wash water over a nest of two sieves consisting of a 2.00-mm (No. 10) or 1.18-mm (No. 16) sieve superimposed on a 75-µm (No. 200) sieve (Note 6). The use of a large spoon or similar device is recommended to aid the process of agitating the contents of the container. Limit agitation by mechanical washing equipment to a maximum of 10 min.

Note 5—There should be enough wetting agent to produce a small amount of suds when the sample is agitated. The quantity will depend on the hardness of the water, the quality of the detergent, and the agitation process. Excessive suds may overflow the sieves and carry some material with them.

Note 6—When mechanical washing equipment is used, the introduction of water, agitating, and decanting may be a continuous operation.

7.3. Vigorously agitate the sample, bringing the particles finer than the 75-µm (No. 200) sieve into suspension. Decant the suspension over the sieve nest in order to completely separate the fine particles from the coarse particles. Use care to avoid, as much as possible, the decantation of the coarse particles of the sample onto the sieve nest. Repeat the operation until the wash water is clear. Do not overflow or overload the 75-µm (No. 200) sieve.

7.4. Return all material retained on the nested sieves to the container. Dry the washed aggregate in the container to constant mass in accordance with T 255 and determine its mass to the nearest 0.1 percent.

7.5. Sieve the aggregate over various sieve sizes, including the 75-µm (No. 200) sieve as required by the specification covering the asphalt mixtures. Additional sieve sizes may be used to regulate the amount of material on a sieve to meet the requirements of Section 7.6. Nest the sieves in order of decreasing size of opening from top to bottom and place the sample on the top sieve. Agitate the sieves by a mechanical apparatus for a sufficient period, established by trial or checked by
measurement on the actual test sample, to meet the criterion for adequacy of sieving described in Section 7.7.

7.6. Limit the quantity of material on a given sieve so that all particles have the opportunity to reach sieve openings a number of times during the sieving operation. Do not exceed a mass of 7 kg/m² (4 g/in.²) retained per sieving surface on any sieve with openings smaller than 4.75 mm (No. 4) at the completion of the sieving operation (Note 7). Do not exceed a mass in kg of the product of 2.5 × (sieve opening in mm) × (the effective or clear sieving surface area, m²) for sieves with openings 4.75 mm (No. 4) and larger. For sieves with openings 4.75 mm (No. 4) and larger, this mass is shown in Table 1 for five sieve-frame dimensions in common use. Do not cause permanent deformation of the sieve cloth due to overloading.

Note 7—The 7 kg/m² (4 g/in.²) amounts to 200 g for the usual 203-mm (8-in.) diameter sieve [with effective or clear sieving surface diameter of 190.5 mm (7½ in.)] or 450 g for a 305-mm (12-in.) diameter sieve [with effective or clear sieving surface diameter of 292.1 mm (11½ in.)]. The amount of material retained on a sieve may be regulated by: (1) the introduction of a sieve with larger openings immediately above the given sieve, (2) testing the sample in a number of increments, or (3) testing the sample over a nest of sieves with a larger sieve-frame dimension.

### Table 1—Maximum Allowable Mass of Material Retained on a Sieve, kg

<table>
<thead>
<tr>
<th>Sieve Opening Size</th>
<th>Nominal Dimensions of Sieve&lt;sup&gt;a&lt;/sup&gt;</th>
<th>203.2 mm, dia&lt;sup&gt;b&lt;/sup&gt;</th>
<th>254 mm, dia&lt;sup&gt;b&lt;/sup&gt;</th>
<th>304.8 mm, dia&lt;sup&gt;b&lt;/sup&gt;</th>
<th>350 by 350 mm</th>
<th>372 by 580 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>125 mm (5 in.)</td>
<td></td>
<td>0.0285</td>
<td>0.0457</td>
<td>0.0670</td>
<td>0.1225</td>
<td>0.2158</td>
</tr>
<tr>
<td>100 mm (4 in.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90 mm (3½ in.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75 mm (3 in.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63 mm (2½ in.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 mm (2 in.)</td>
<td></td>
<td>3.6</td>
<td>5.7</td>
<td>8.4</td>
<td>15.3</td>
<td>27.0</td>
</tr>
<tr>
<td>37.5 mm (1½ in.)</td>
<td></td>
<td>2.7</td>
<td>4.3</td>
<td>6.3</td>
<td>11.5</td>
<td>20.2</td>
</tr>
<tr>
<td>25.0 mm (1 in.)</td>
<td></td>
<td>1.8</td>
<td>2.9</td>
<td>4.2</td>
<td>7.7</td>
<td>13.5</td>
</tr>
<tr>
<td>19.0 mm (¾ in.)</td>
<td></td>
<td>1.4</td>
<td>2.2</td>
<td>3.2</td>
<td>5.8</td>
<td>10.2</td>
</tr>
<tr>
<td>12.5 mm (½ in.)</td>
<td></td>
<td>0.89</td>
<td>1.4</td>
<td>2.1</td>
<td>3.8</td>
<td>6.7</td>
</tr>
<tr>
<td>9.5 mm (⅛ in.)</td>
<td></td>
<td>0.67</td>
<td>1.1</td>
<td>1.6</td>
<td>2.9</td>
<td>5.1</td>
</tr>
<tr>
<td>4.75 mm (No. 4)</td>
<td></td>
<td>0.33</td>
<td>0.54</td>
<td>0.80</td>
<td>1.5</td>
<td>2.6</td>
</tr>
</tbody>
</table>

<sup>a</sup> Sieve-frame dimensions in inch units: 8.0-in. diameter; 10.0-in. diameter; 12.0-in. diameter; 13.8 by 13.8 in. (14 by 14 in. nominal); 14.6 by 22.8 in. (16 by 24 in. nominal).

<sup>b</sup> The sieve area for round sieves is based on an effective or clear diameter of 12.7 mm (½ in.) less than the nominal frame diameter because ASTM E11 permits the sealer between the sieve cloth and the frame to extend 6.35 mm (¼ in.) over the sieve cloth. Thus the effective or clear sieving diameter for a 203.2-mm (8.0-in.) diameter sieve frame is 190.5 mm (7½ in.). Sieves produced by some manufacturers do not infringe on the sieve cloth by the full 6.35 mm (¼ in.).

<sup>c</sup> Sieves indicated have less than five full openings and should not be used for sieve testing.

7.7. Continue sieving for a sufficient period and in such manner that, after completion, not more than 0.5 percent by mass of the total sample passes any sieve during 60 s of continuous hand-sieving performed as follows: Hold the individual sieve, provided with a snug-fitting pan and cover, in a slightly inclined position in one hand. Strike the side of the sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per min, turning the sieve about one-sixth of a revolution at intervals of about 25 strokes. In determining the adequacy of sieving for sizes larger than the 4.75-mm (No. 4) sieve, limit the material on the sieve to a single layer of particles. If the size of the mounted testing sieves makes the described sieving motion impractical, use 203-mm (8-in.) diameter sieves to verify the adequacy of sieving.
8. **CALCULATIONS**

8.1. Record the mass of material passing each sieve, the mass retained on the next sieve, and the amount passing the 75-µm (No. 200) sieve. The sum of these masses must be within 0.2 percent of the mass after washing. Add the mass of dry material passing the 75-µm (No. 200) sieve by dry sieving to the mass removed by washing, and if applicable, the mass of mineral matter in the asphalt binder, in order to obtain the total passing the 75-µm (No. 200) sieve. Convert the masses of fractions retained on the various sieves and the total passing the 75-µm (No. 200) sieve to percentages by dividing each by the initial specimen mass determined in Section 7.1.1 or 7.1.2, as applicable.

8.2. For aggregate samples obtained from T 308, apply the aggregate correction factor, as required in T 308, to obtain the final total passing percentages.

9. **REPORT**

9.1. Report the results of the sieve analysis as follows: (a) total percentages passing each sieve; or (b) total percentages retained on each sieve; or (c) percentages retained between consecutive sieves, depending on the form of the specifications of the material being tested. Report percentages to the nearest whole number, except for the percentage passing the 75-µm (No. 200) sieve, which shall be reported to the nearest 0.1 percent.

10. **PRECISION AND BIAS**

10.1. *Precision*—The estimates of precision for this test method are listed in Table 2. The estimates are based on the results from the AASHTO re:source Proficiency Sample Program, with testing conducted according to T 30. The data are based on the analyses of the test results from 47 to 190 laboratories that tested 17 pairs of proficiency test samples (Samples No. 1 through 34). The values in the table are given for different ranges of total percentage of aggregate passing a sieve.

<table>
<thead>
<tr>
<th>Table 2—Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Percentage of Material Passing a Sieve</td>
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<tr>
<td>--------------------</td>
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<tr>
<td><strong>Extracted aggregate:</strong></td>
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<tr>
<td>Single-operator precision</td>
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<td></td>
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<tr>
<td>Multilaboratory precision</td>
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</tr>
</tbody>
</table>

* These numbers represent, respectively, the (1s) and (d2s) limits described in ASTM C670.

* The precision estimates are based on aggregates with nominal maximum sizes of 19.0 mm (3/4 in.) to 9.5 mm (3/8 in.).
10.2. *Bias*—This test method has no bias because the values determined can only be defined in terms of this test method.

11. **KEYWORDS**

11.1. Coarse aggregate; fine aggregate; particle size; sieves.
Standard Method of Test for

Specific Gravity and Absorption of Fine Aggregate

AASHTO Designation: T 84-13 (2017)¹
Technical Section: 1c, Aggregates
Release: Group 3 (August)
ASTM Designation: C128-12
1. SCOPE

1.1. This method covers the determination of bulk and apparent specific gravity, 23/23°C (73.4/73.4°F), and absorption of fine aggregate.

1.2. This method determines (after 15–19 h of soaking in water) the bulk specific gravity and the apparent specific gravity, the bulk specific gravity on the basis of mass of saturated surface-dry (SSD) aggregate, and the absorption.

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

1.4. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this procedure to consult and establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to its use.*

2. REFERENCED DOCUMENTS

2.1. AASHTO Standards:

- M 6, Fine Aggregate for Hydraulic Cement Concrete
- M 231, Weighing Devices Used in the Testing of Materials
- R 76, Reducing Samples of Aggregate to Testing Size
- R 90, Sampling Aggregate Products
- T 11, Materials Finer Than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing
- T 19M/T 19, Bulk Density (“Unit Weight”) and Voids in Aggregate
- T 85, Specific Gravity and Absorption of Coarse Aggregate
- T 100, Specific Gravity of Soils
- T 133, Density of Hydraulic Cement
- T 255, Total Evaporable Moisture Content of Aggregate by Drying

2.2. ASTM Standard:

- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
3. TERMINOLOGY

3.1. Definitions:

3.1.1. absorption—the increase in the mass of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass. The aggregate is considered “dry” when it has been maintained at a temperature of 110 ± 5°C for sufficient time to remove all uncombined water by reaching a constant mass.

3.1.2. specific gravity—the ratio of the mass (or weight in air) of a unit volume of a material to the mass of the same volume of gas-free distilled water at stated temperatures. Values are dimensionless.

3.1.2.1. apparent specific gravity—the ratio of the weight in air of a unit volume of the impermeable portion of aggregate at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

3.1.2.2. bulk specific gravity—the ratio of the weight in air of a unit volume of aggregate (including the permeable and impermeable voids in the particles, but not including the voids between particles) at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

3.1.2.3. bulk specific gravity (SSD)—the ratio of the mass in air of a unit volume of aggregate, including the mass of water within the voids filled to the extent achieved by submerging in water for 15–19 h (but not including the voids between particles) at a stated temperature, compared to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

4. SIGNIFICANCE AND USE

4.1. Bulk specific gravity is the characteristic generally used for calculation of the volume occupied by the aggregate in various mixtures containing aggregate including portland cement concrete, bituminous concrete, and other mixtures that are proportioned or analyzed on an absolute volume basis. Bulk specific gravity is also used in the computation of voids in aggregate in T 19M/T 19. Bulk specific gravity determined on the SSD basis is used if the aggregate is wet; that is, if its absorption has been satisfied. Conversely, the bulk specific gravity determined on the oven-dry basis is used for computations when the aggregate is dry or assumed to be dry.

4.2. Apparent specific gravity pertains to the relative density of the solid material making up the constituent particles not including the pore space within the particles that is accessible to water. This value is not widely used in construction aggregate technology.

4.3. Absorption values are used to calculate the change in the mass of an aggregate due to water absorbed in the pore spaces within the constituent particles, compared to the dry condition, when it is deemed that the aggregate has been in contact with water long enough to satisfy most of the absorption potential. The laboratory standard for absorption is that obtained after soaking dry aggregate in water. Aggregates mined from below the water table may have a higher absorption when used, if not allowed to dry. Conversely, some aggregates when used may contain an amount of absorbed moisture less than that achieved by the required amount of soaking time: For an aggregate that has been in contact with water and that has free moisture on the particle surfaces, the percentage of free moisture can be determined by deducting the absorption from the total moisture content determined by T 255 by drying.
5. **APPARATUS**

5.1. *Balance*, conforming to the requirements of M 231, Class G 2.

5.2. *Pycnometer*—A flask or other suitable container into which the fine aggregate test sample can be readily introduced and in which the volume content can be reproduced with ±100 mm$^3$. The volume of the container filled to mark shall be at least 50 percent greater than the space required to accommodate the test sample. A volumetric flask of 500-mL capacity or a fruit jar fitted with a pycnometer top is satisfactory for a 500-g test sample of most fine aggregates. A Le Chatelier flask as described in T 133 is satisfactory for an approximately 55-g test sample.

5.3. *Mold*—A metal mold in the form of a frustum of a cone with dimensions as follows: 40 ± 3 mm inside diameter at the top, 90 ± 3 mm inside diameter at the bottom, and 75 ± 3 mm in height, with the metal having a minimum thickness of 0.8 mm.

5.4. *Tamper*—A metal tamper having a mass of 340 ± 15 g and having a flat circular tamping face 25 ± 3 mm in diameter.

6. **SAMPLING**

6.1. Sampling shall be accomplished in general accordance with R 90.

7. **PREPARATION OF TEST SPECIMEN**

7.1. Obtain approximately 1 kg of the fine aggregate from the sample using the applicable procedures described in R 76.

7.1.1. Dry it in a suitable pan or vessel to constant mass at a temperature of 110 ± 5°C (230 ± 9°F). Allow it to cool to comfortable handling temperature, cover with water, either by immersion or by the addition of at least 6 percent moisture to the fine aggregate and permit to stand for 15 to 19 h.

7.1.2. As an alternative to Section 7.1.1, where the absorption and specific gravity values are to be used in proportioning concrete mixtures with aggregates used in their naturally moist condition, the requirement for initial drying to constant mass may be eliminated and, if the surfaces of the particles have been kept wet, the required soaking may also be eliminated.

**Note 1**—Values for absorption and for specific gravity in the SSD condition may be significantly higher for aggregate not oven dried before soaking than for the same aggregate treated in accordance with Section 7.1.1.

7.2. Decant excess water with care to avoid loss of fines, spread the sample on a flat, nonabsorbent surface exposed to a gently moving current of warm air, and stir frequently to secure homogeneous drying. If desired, mechanical aids such as tumbling or stirring may be employed to assist in achieving the SSD condition. As the material begins to dry sufficiently, it may be necessary to work it with the hands in a rubbing motion to break up any conglomerations, lumps, or balls of material that develop. Continue this operation until the test specimen approaches a free-flowing condition. Follow the procedure in Section 7.2.1 to determine whether or not surface moisture is present on the constituent fine aggregate particles. It is intended that the first trial of the cone test will be made with some surface water in the specimen. Continue drying with constant stirring, and, if necessary, work the material with a hand-rubbing motion, and test at frequent intervals until the test indicates that the specimen has reached a surface-dry condition. If the first trial of the surface moisture test indicates that moisture is not present on the surface, it has been dried past the SSD condition. In this case, thoroughly mix a few milliliters of water with the fine aggregate particles using the mold and tamper.
aggregate and permit the specimen to stand in a covered container for 30 min. Then resume the process of drying and testing at frequent intervals for the onset of the surface-dry condition.

7.2.1. Cone Test for Surface Moisture—Hold the mold firmly on a smooth nonabsorbent surface with the large diameter down. Place a portion of the partially dried fine aggregate loosely in the mold by filling until overflow occurs and heaping additional material above the top of the mold by holding it with the cupped fingers of the hand holding the mold. Lightly tamp the fine aggregate into the mold with 25 light drops of the tamper. Each drop should start about 5 mm (0.2 in.) above the top surface of the fine aggregate. Permit the tamper to fall freely under gravitational attraction on each drop. Adjust the starting height to the new surface elevation after each drop and distribute the drops over the surface. Remove loose sand from the base and lift the mold vertically. If surface moisture is still present, the fine aggregate will retain the molded shape. When the fine aggregate slumps slightly, it indicates that it has reached a surface-dry condition. Some angular fine aggregate or material with a high proportion of fines may not slump in the cone test upon reaching a surface-dry condition. This may be the case if fines become airborne upon dropping a handful of the sand from the cone test 100 to 150 mm onto a surface. For these materials, the SSD condition should be considered as the point when one side of the fine aggregate slumps slightly upon removing the mold.

Note 2—The following criteria have also been used on materials that do not readily slump:

1. Provisional Cone Test—Fill the cone mold as described in Section 7.2.1, except only use 10 drops of the tamper. Add more fine aggregate and use 10 drops of the tamper again. Then add material two more times using three and two drops of the tamper, respectively. Level off the material even with the top of the mold, remove loose material from the base, and lift the mold vertically.

2. Provisional Surface Test—If airborne fines are noted when the fine aggregate is such that it will not slump when it is at a moisture condition, add more moisture to the sand, and at the onset of the surface-dry condition, with the hand lightly pat approximately 100 g of the material on a flat, dry, clean, dark, or dull nonabsorbent surface such as a sheet of rubber, a worn oxidized, galvanized, or steel surface, or a black-painted metal surface. After 1 to 3 s, remove the fine aggregate. If noticeable moisture shows on the test surface for more than 1 to 2 s, then surface moisture is considered to be present on the fine aggregate.

3. Colorimetric procedures described by Kandhal and Lee, *Highway Research Record No. 307*, p. 44.

4. For reaching the SSD condition on a single-size material that slumps when wet, hard-finish paper towels can be used to surface-dry the material until the point is just reached where the paper towel does not appear to be picking up moisture from the surfaces of the fine aggregate particles.

8. PROCEDURE

8.1. Make and record all mass determinations to 0.1 g.

8.2. Partially fill the pycnometer with water. Immediately introduce into the pycnometer 500 ± 10 g of SSD fine aggregate prepared as described in Section 7, and fill with additional water to approximately 90 percent of capacity. Manually roll, invert, and agitate or use a combination of these actions to eliminate all air bubbles in the pycnometer (Note 3). Accomplish mechanical agitation by external vibration of the pycnometer in a manner that will not degrade the sample. A level of agitation adjusted to just set individual particles in motion is sufficient to promote de-airing without degradation. A mechanical agitator shall be considered acceptable for use if comparison tests for each six-month period of use show variations less than the acceptable range of two results (d2s) indicated in Table 1 from results of manual agitation on the same material. Adjust its temperature to 23.0 ± 1.7°C (73.4 ± 3°F), if necessary by immersion in circulating water, and bring the water level in the pycnometer to its calibrated capacity. Determine total mass of the pycnometer, specimen, and water.
Note 3—It normally takes about 15 to 20 min to eliminate air bubbles by manual methods. Dipping the tip of a paper towel into the pycnometer has been found to be useful in dispersing the foam that sometimes builds up when eliminating the air bubbles. Adding a few drops of isopropyl alcohol, after removal of air bubbles and just prior to bringing the water level to its calibrated capacity, has also been found useful in dispersing foam on the water surface. Do not use isopropyl alcohol when using the alternative method described in Section 8.2.1.

Table 1—Precision

<table>
<thead>
<tr>
<th></th>
<th>Standard Deviation (1s)</th>
<th>Acceptable Range of Two Results (d2s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single-operator precision:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulk specific gravity (dry)</td>
<td>0.011</td>
<td>0.032</td>
</tr>
<tr>
<td>Bulk specific gravity (SSD)</td>
<td>0.0095</td>
<td>0.027</td>
</tr>
<tr>
<td>Apparent specific gravity</td>
<td>0.0095</td>
<td>0.027</td>
</tr>
<tr>
<td>Absorption, percent</td>
<td>0.11</td>
<td>0.31</td>
</tr>
<tr>
<td><strong>Multilaboratory precision:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulk specific gravity (dry)</td>
<td>0.023</td>
<td>0.066</td>
</tr>
<tr>
<td>Bulk specific gravity (SSD)</td>
<td>0.020</td>
<td>0.056</td>
</tr>
<tr>
<td>Apparent specific gravity</td>
<td>0.020</td>
<td>0.056</td>
</tr>
<tr>
<td>Absorption, percent</td>
<td>0.23</td>
<td>0.66</td>
</tr>
</tbody>
</table>

a These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM C670. The precision estimates were obtained from the analysis of combined AASHTO Materials Reference Laboratory reference sample data from laboratories using 15- to 19-h saturation times and other laboratories using 24 ± 4 h of saturation time. Testing was performed on aggregates of normal specific gravities, and started with aggregates in the oven-dry condition.

b Precision estimates are based on aggregates with absorptions of less than 1 percent and may differ for manufactured fine aggregates having absorption values greater than 1 percent.

8.2.1. Alternative to Determining the Mass in Section 8.2—The quantity of added water necessary to fill the pycnometer at the required temperature may be determined volumetrically using a buret accurate to 0.15 mL. Compute the total mass of the pycnometer, specimen, and water as follows:

\[
C = 0.9975 V_a + S + W
\]

where:
\[
C = \text{mass of pycnometer with specimen and water to calibration mark, g;}
\]
\[
V_a = \text{volume of water added to pycnometer, mL;}
\]
\[
S = \text{mass of SSD specimen, g; and}
\]
\[
W = \text{mass of the pycnometer empty, g.}
\]

8.2.2. Alternative to the Procedure in Section 8.2—Use a Le Chatelier flask initially filled with water to a point on the stem between the 0- and the 1-mL mark. Record this initial reading with the flask and contents within the temperature range of 23.0 ± 1.7°C (73.4 ± 3°F). Add 55 ± 5 g of fine aggregate in the SSD condition (or other mass as necessary to result in raising the water level to some point on the upper series of graduation). After all fine aggregate has been introduced, place the stopper in the flask and roll the flask in an inclined position, or gently whirl it in a horizontal circle so as to dislodge all entrapped air, continuing until no further bubbles rise to the surface (Note 4). Take a final reading with the flask and contents within 1°C (1.8°F) of the original temperature.

Note 4—When using the Le Chatelier flask method, slowly adding a small measured amount (not to exceed 1 mL) of isopropyl alcohol, after removal of air bubbles, has been found useful in dispersing foam appearing on the water surface. The volume of alcohol used must be subtracted from the final reading (R₂).
8.3. Remove the fine aggregate from the pycnometer, dry to constant mass at a temperature of 110 ± 5°C (230 ± 9°F), cool in air at room temperature for 1.0 ± 0.5 h and determine the mass.

Note 5—In lieu of drying and determining the mass of the sample that has been removed from the pycnometer, a second portion of the SSD sample may be used to determine the oven-dry mass. This sample must be obtained at the same time and be within 0.2 grams of the mass of the sample that is introduced into the pycnometer.

8.3.1. If the Le Chatelier flask method is used, a separate sample portion is needed for the determination of absorption. Weigh a separate 500 ± 10 g portion of the SSD fine aggregate, dry to constant mass, and reweigh. This sample must be obtained at the same time as the sample that is introduced into the Le Chatelier flask.

8.4. Determine the mass of the pycnometer filled to its calibration capacity with water at 23.0 ± 1.7°C (73.4 ± 3°F).

8.4.1. Alternative to Determining the Mass in Section 8.4—The quantity of water necessary to fill the empty pycnometer at the required temperature may be determined volumetrically using a buret accurate to 0.15 mL. Calculate the mass of the pycnometer filled with water as follows:

\[ B = 0.9975V + W \]  \( (2) \)

where:

- \( B \) = mass of flask filled with water, g;
- \( V \) = volume of flask, mL; and
- \( W \) = mass of the flask empty, g.

9. BULK SPECIFIC GRAVITY

9.1. Calculate the bulk specific gravity, 23/23°C (73.4/73.4°F), as follows:

\[ \text{bulk sp gr} = \frac{A}{B + S - C} \]  \( (3) \)

where:

- \( A \) = mass of oven-dry specimen in air, g;
- \( B \) = mass of pycnometer filled with water, g;
- \( S \) = mass of SSD specimen, g; and
- \( C \) = mass of pycnometer with specimen and water to calibration mark, g.

9.1.1. If the Le Chatelier flask method was used, calculate the bulk specific gravity, 23/23°C, as follows:

\[ \text{bulk sp gr} = \frac{S_1 \left( \frac{A}{S} \right)}{0.9975 \left( R_2 - R_1 \right)} \]  \( (4) \)

where:

- \( S_1 \) = mass of SSD specimen used in Le Chatelier flask, g;
- \( R_2 \) = final reading of water level in Le Chatelier flask; and
- \( R_1 \) = initial reading of water level in Le Chatelier flask.

10. BULK SPECIFIC GRAVITY (SATURATED SURFACE-DRY BASIS)

10.1. Calculate the bulk specific gravity, 23/23°C (73.4/73.4°F), on the basis of mass of SSD aggregate as follows:
bulk sp gr (saturated surface-dry basis) = \( S/(B + S - C) \)  

(5)

10.1.1. If the Le Chatelier flask method was used, calculate the bulk specific gravity, 23/23°C, on the basis of SSD aggregate as follows:

\[
\text{bulk sp gr (saturated surface-dry basis)} = \frac{S_i}{0.9975(R_2 - R_1)}
\]

(6)

11. APPARENT SPECIFIC GRAVITY

11.1. Calculate the apparent specific gravity, 23/23°C (73.4/73.4°F) as follows:

\[
\text{apparent sp gr} = \frac{A}{(B + A - C)}
\]

(7)

12. ABSORPTION

12.1. Calculate the percentage of absorption as follows:

\[
\text{absorption, percent} = \left( \frac{S - A}{A} \right) \times 100
\]

(8)

13. REPORT

13.1. Report specific gravity results to the nearest 0.001 (Fine Aggregate meeting M 6 requirements may be reported to the nearest 0.01) and absorption to the nearest 0.1 percent. The Appendix gives mathematical interrelationships among the three types of specific gravities and absorption. These may be useful in checking the consistency of reported data or calculating a value that was not reported by using other reported data.

13.2. If the fine aggregate was tested in a naturally moist condition other than the oven-dried and 15-h soaked condition, report the source of the sample and the procedures used to prevent drying prior to testing.

14. PRECISION AND BIAS

14.1. The estimates of precision of this test method (listed in Table 1) are based on results from the AASHTO Materials Reference Laboratory Reference Sample Program, with testing conducted by this test method and ASTM C128. The significant difference between the methods is that ASTM C128 requires a saturation period of 24 ± 4 h, and T 84 requires a saturation period of 15 to 19 h. This difference has been found to have an insignificant effect on the precision indices. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories.

14.2. Because there is no accepted reference material suitable for determining the bias for the procedure in T 84 for measuring specific gravity and absorption of fine aggregate, no statement on bias is being made.

15. KEYWORDS

15.1. Absorption; fine aggregate; pycnometer; saturated surface-dry (SSD); specific gravity.
APPENDIXES

(Nonmandatory Information)

X1. POTENTIAL DIFFERENCES IN BULK SPECIFIC GRAVITY AND ABSORPTION DUE TO PRESENCE OF MATERIAL FINER THAN 75 µM (NO. 200)

X1.1. It has been found that there may be significant differences in bulk specific gravity and absorption between fine aggregate samples tested with the material finer than 75 µm (No. 200) present and not present in the samples. Samples from which the material finer than 75 µm is not removed usually give a higher absorption and a lower bulk specific gravity compared with testing the same fine aggregate from which the material finer than 75 µm is removed following the procedures of T 11. Samples with material finer than 75 µm may build up a coating around the coarser fine aggregate particles during the surface-drying process. The resultant specific gravity and absorption that is subsequently measured is that of the agglomerated and coated particles and not that of the parent material. The difference in absorption and specific gravity determined between samples from which the material finer than 75 µm have not been removed and samples from which the material finer than 75 µm have been removed depends on both the amount of the material finer than 75 µm present and the nature of the material. When the material finer than 75 µm is less than about 4 percent by mass, the difference in specific gravity between washed and unwashed samples is less than 0.03. When the material finer than 75 µm is greater than about 8 percent by mass, the difference in specific gravity obtained between washed and unwashed samples may be as great as 0.13.

X1.2. The material finer than 75 µm, which is removed, can be assumed to have the same specific gravity as the fine aggregate. Alternatively, the specific gravity of the material finer than 75 µm may be further evaluated using T 100; however, this test determines the apparent specific gravity and not the bulk specific gravity.

X2. INTERRELATIONSHIPS BETWEEN SPECIFIC GRAVITIES AND ABSORPTION AS DEFINED IN T 84 AND T 85

X2.1. Let:

\[ S_d = \text{bulk specific gravity (dry-basis)}, \]
\[ S_s = \text{bulk specific gravity (SSD-basis)}, \]
\[ S_a = \text{apparent specific gravity}, \]
\[ A = \text{absorption in percent}. \]

Then:

\[ S_s = (1 + A/100)S_d \quad (X1.1) \]

\[ S_a = \frac{1}{\frac{1}{S_d} - \frac{A}{100}} = \frac{S_d}{1 - \frac{A S_d}{100}} \quad (X1.2) \]

Or:
\[ S_s = \frac{1}{1 + \frac{A}{100}} - \frac{A}{100} \left(1 - \frac{S_s}{S_s - 1}\right) \]  \hspace{1cm} (X1.3)

\[ A = \left(\frac{S_s}{S_s - 1}\right) \times 100 \]  \hspace{1cm} (X1.4)

\[ A = \left(\frac{S_s - S_d}{S_s (S_s - 1)}\right) \times 100 \]  \hspace{1cm} (X1.5)

\(^1\text{This method is technically equivalent to ASTM C128-12.}\)
Standard Method of Test for
Specific Gravity and Absorption
of Coarse Aggregate

Technical Section: 1c, Aggregates
Release: Group 3 (August)
ASTM Designation: C127-12
Standard Method of Test for

Specific Gravity and Absorption of Coarse Aggregate

AASHTO Designation: T 85-14 (2018)¹
Technical Section: 1c, Aggregates
Release: Group 3 (August)
ASTM Designation: C127-12

1. SCOPE

1.1. This method covers the determination of specific gravity and absorption of coarse aggregate. The specific gravity may be expressed as bulk specific gravity, bulk specific gravity (saturated surface-dry (SSD)), or apparent specific gravity. The bulk specific gravity (SSD) and absorption are based on aggregate after 15–19 h of soaking in water. This method is not intended to be used with lightweight aggregates.

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

1.3. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this procedure to consult and establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to its use.

2. REFERENCED DOCUMENTS

2.1. AASHTO Standards:

- M 43, Sizes of Aggregate for Road and Bridge Construction
- M 80, Coarse Aggregate for Hydraulic Cement Concrete
- M 231, Weighing Devices Used in the Testing of Materials
- R 76, Reducing Samples of Aggregate to Testing Size
- R 90, Sampling Aggregate Products
- T 19M/T 19, Bulk Density (“Unit Weight”) and Voids in Aggregate
- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 84, Specific Gravity and Absorption of Fine Aggregate
- T 255, Total Evaporable Moisture Content of Aggregate by Drying

2.2. ASTM Standards:

- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- E11, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves
3. TERMINOLOGY

3.1. Definitions:

3.1.1. absorption—the increase in the mass of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass. The aggregate is considered “dry” when it has been maintained at a temperature of 110 ± 5°C for sufficient time to remove all uncombined water by reaching a constant mass.

3.1.2. specific gravity—the ratio of the mass (or weight in air) of a unit volume of a material to the mass of the same volume of gas-free distilled water at stated temperatures. Values are dimensionless.

3.1.2.1. apparent specific gravity—the ratio of the weight in air of a unit volume of the impermeable portion of aggregate at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

3.1.2.2. bulk specific gravity—the ratio of the weight in air of a unit volume of aggregate (including the permeable and impermeable voids in the particles, but not including the voids between particles) at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

3.1.2.3. bulk specific gravity (SSD)—the ratio of the mass in air of a unit volume of aggregate, including the mass of water within the voids filled to the extent achieved by submerging in water for 15–19 h (but not including the voids between particles) at a stated temperature, compared to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

4. SUMMARY OF METHOD

4.1. A sample of aggregate is immersed in water to essentially fill the pores. It is then removed from the water, the water dried from the surface of the particles, and weighed. Subsequently the sample is weighed while submerged in water. Finally, the sample is oven-dried and weighed a third time. Using the mass and weight measurements thus obtained and formulas in the method, it is possible to calculate three types of specific gravity and absorption.

5. SIGNIFICANCE AND USE

5.1. Bulk specific gravity is the characteristic generally used for calculation of the volume occupied by the aggregate in various mixtures containing aggregate, including portland cement concrete, bituminous concrete, and other mixtures that are proportioned or analyzed on an absolute volume basis. Bulk specific gravity is also used in the computation of voids in aggregate in T 19M/T 19. Bulk specific gravity (SSD) is used if the aggregate is wet, that is, if its absorption has been satisfied. Conversely, the bulk specific gravity (oven-dry) is used for computations when the aggregate is dry or assumed to be dry.

5.2. Apparent specific gravity pertains to the relative density of the solid material making up the constituent particles, not including the pore space within the particles that is accessible to water.

5.3. Absorption values are used to calculate the change in the mass of an aggregate due to water absorbed in the pore spaces within the constituent particles, compared to the dry condition, when it is deemed that the aggregate has been in contact with water long enough to satisfy most of the absorption potential. The laboratory standard for absorption is that obtained after soaking dry aggregate in water. Aggregates mined from below the water table may have a higher absorption,
when used, if not allowed to dry. Conversely, some aggregates when used may contain an amount of absorbed moisture less than the required amount of time to achieve the soaked condition. For an aggregate that has been in contact with water and that has free moisture on the particle surfaces, the percentage of free moisture can be determined by deducting the absorption from the total moisture content determined by T 255.

5.4. The general procedures described in this method are suitable for determining the absorption of aggregates that have had conditioning other than the required soak, such as boiling water or vacuum saturation. The values obtained for absorption by other methods will be different than the values obtained by the required soak, as will the bulk specific gravity (SSD).

5.5. The pores in lightweight aggregates may or may not become essentially filled with water after the required soaking period. In fact, many such aggregates can remain immersed in water for several days without satisfying most of the aggregates’ absorption potential. Therefore, this method is not intended for use with lightweight aggregate.

6. APPARATUS

6.1. Balance—Conforming to the requirements of M 231, Class G 5. The balance shall be equipped with suitable apparatus for suspending the sample container in water from the center of the weighing platform or pan of the balance.

6.2. Sample Container—A wire basket of 3.35 mm (No. 6) or finer mesh, or a bucket of approximately equal breadth and height, with a capacity of 4 to 7 L for 37.5-mm (1 1/2-in.) nominal maximum size aggregate or smaller, and a larger container as needed for testing larger maximum size aggregate. The container shall be constructed so as to prevent trapping air when the container is submerged.

6.3. Water Tank—A watertight tank into which the sample and container are placed for complete immersion while suspended below the balance, equipped with an overflow outlet for maintaining a constant water level.

6.4. Suspended Apparatus—Wire suspending the container shall be of the smallest practical size to minimize any possible effects of a variable immersed length.

6.5. Sieves—A 4.75-mm (No. 4) sieve or other sizes as needed (Sections 7.2, 7.3, and 7.4), conforming to ASTM E11.

7. SAMPLING

7.1. Sample the aggregate in accordance with R 90.

7.2. Thoroughly mix the sample of aggregate and reduce it to the approximate quantity needed using the applicable procedures in R 76. Reject all material passing a 4.75-mm (No. 4) sieve by dry-sieving and thoroughly washing to remove dust or other coatings from the surface. If the coarse aggregate contains a substantial quantity of material finer than the 4.75-mm (No. 4) sieve (such as for Size No. 8 and 9 aggregates in M 43), use the 2.36-mm (No. 8) sieve in place of the 4.75-mm (No. 4) sieve. Alternatively, separate the material finer than the 4.75-mm (No. 4) sieve and test the finer material according to T 84.

7.3. The minimum mass of test sample to be used is given below. In many instances, it may be desirable to test a coarse aggregate in several separate size fractions; and if the sample contains more than 15 percent retained on the 37.5-mm (1 1/2-in.) sieve, test the material larger than 37.5 mm in one or more size fractions separately from the smaller size fractions. When an aggregate is tested in separate size fractions, the minimum mass of test sample for each fraction
shall be the difference between the masses prescribed for the maximum and minimum sizes of
the fraction.

<table>
<thead>
<tr>
<th>Nominal Maximum Size, mm (in.)</th>
<th>Minimum Mass of Test Sample, kg (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5 (1/2) or less</td>
<td>2 (4.4)</td>
</tr>
<tr>
<td>19.0 (1)</td>
<td>3 (6.6)</td>
</tr>
<tr>
<td>25.0 (1)</td>
<td>4 (8.8)</td>
</tr>
<tr>
<td>37.5 (1 1/2)</td>
<td>5 (11)</td>
</tr>
<tr>
<td>50 (2)</td>
<td>8 (18)</td>
</tr>
<tr>
<td>63 (2 1/2)</td>
<td>12 (26)</td>
</tr>
<tr>
<td>75 (3)</td>
<td>18 (40)</td>
</tr>
<tr>
<td>90 (3 1/2)</td>
<td>25 (55)</td>
</tr>
<tr>
<td>100 (4)</td>
<td>40 (88)</td>
</tr>
<tr>
<td>112 (4 1/2)</td>
<td>50 (110)</td>
</tr>
<tr>
<td>125 (5)</td>
<td>75 (165)</td>
</tr>
<tr>
<td>150 (6)</td>
<td>125 (276)</td>
</tr>
</tbody>
</table>

7.4. If the sample is tested in two or more size fractions, determine the grading of the sample in
accordance with T 27, including the sieves used for separating the size fractions for the
determinations in this method. In calculating the percentage of material in each size fraction,
ignore the quantity of material finer than the 4.75-mm (No. 4) sieve or 2.36-mm (No. 8) sieve
when that sieve is used in accordance with Section 7.2.

8. PROCEDURE

8.1. Dry the test sample to constant mass at a temperature of 110 ± 5°C (230 ± 9°F), cool in air at room
temperature for 1 to 3 h for test samples of 37.5-mm (1 1/2-in.) nominal maximum size, or longer
for larger sizes, until the aggregate has cooled to a temperature that is comfortable to handle
(approximately 50°C). Subsequently immerse the aggregate in water at room temperature for a
period of 15 to 19 h.

Note 1—When testing coarse aggregate of large nominal maximum size requiring large test
samples, it may be more convenient to perform the test on two or more subsamples, and the values
obtained combined for the computation described in Section 9.

8.2. Where the absorption and specific gravity values are to be used in proportioning concrete mixtures
in which the aggregates will be in their naturally moist condition, the requirement for initial drying
to constant mass may be eliminated, and, if the surfaces of the particles in the sample have been
kept continuously wet until test, the required soaking may also be eliminated.

Note 2—Values for absorption and bulk specific gravity (SSD) may be significantly higher for
aggregate not oven dried before soaking than for the same aggregate treated in accordance with
Section 8.1. This is especially true of particles larger than 75 mm (3 in.) because the water may
not be able to penetrate the pores to the center of the particle in the required soaking period.

8.3. Remove the test sample from the water and roll it in a large absorbent cloth until all visible films
of water are removed. Wipe the larger particles individually. A moving stream of air may be used
to assist in the drying operation. Take care to avoid evaporation of water from aggregate pores
during the operation of surface-drying. If the test sample dries past the SSD condition, immerse in
water for 30 min, then resume the process of surface-drying. Determine the mass of the test
sample in the SSD condition. Record this and all subsequent masses to the nearest 1.0 g or
0.1 percent of the sample mass, whichever is greater.
8.4. After determining the mass, immediately place the SSD test sample in the sample container and
determine its mass in water at 23.0 ± 1.7°C (73.4 ± 3°F), having a density of 997 ± 2 kg/m³. Take
care to remove all entrapped air before determining the mass by shaking the container while
immersed. Maintain the water level in the bath at the overflow depth to obtain a constant water
level throughout the test.

**Note 3**—The container should be immersed to a depth sufficient to cover it and the test sample
during mass determination. Wire suspending the container should be of the smallest practical size
to minimize any possible effects of a variable immersed length.

8.5. Dry the test sample to constant mass at a temperature of 110 ± 5°C (230 ± 9°F), cool in air at
room temperature 1 to 3 h, or until the aggregate has cooled to a temperature that is comfortable to
handle (approximately 50°C), and determine the mass. Use this weight for A in the calculations in
Section 9.

9. **CALCULATIONS**

9.1. *Specific Gravity:*

9.1.1. **Bulk Specific Gravity**—Calculate the bulk specific gravity, 23/23°C (73.4/73.4°F), as follows:

\[
\text{bulk sp gr} = \frac{A}{(B - C)}
\]

(1)

where:

- \(A\) = mass of oven-dry test sample in air, g;
- \(B\) = mass of SSD test sample in air, g; and
- \(C\) = mass of saturated test sample in water, g.

9.1.2. **Bulk Specific Gravity (SSD)**—Calculate the bulk specific gravity, 23/23°C (73.4/73.4°F), on the
basis of mass of SSD aggregate as follows:

\[
\text{bulk sp gr (saturated surface-dry)} = \frac{B}{(B - C)}
\]

(2)

9.1.3. **Apparent Specific Gravity**—Calculate the apparent specific gravity, 23/23°C (73.4/73.4°F),
as follows:

\[
\text{apparent sp gr} = \frac{A}{(A - C)}
\]

(3)

9.2. **Average Specific Gravity Values**—When the sample is tested in separate size fractions, the
average value for bulk specific gravity, bulk specific gravity (SSD), or apparent specific gravity
can be computed as the weighted average of the values as computed in accordance with
Section 9.1 using the following equation:

\[
G = \frac{1}{\frac{P_1}{100G_1} + \frac{P_2}{100G_2} + \ldots + \frac{P_n}{100G_n}}
\]

(4)

where:

- \(G\) = average specific gravity (All forms of expression of specific gravity can be
  averaged in this manner.);
- \(P_1, P_2, \ldots, P_n\) = mass percentages of each size fraction present in the original sample; and
- \(G_1, G_2, \ldots, G_n\) = appropriate specific gravity values for each size fraction depending on the type
  of specific gravity being averaged.

**Note 4**—Some users of this method may wish to express the results in terms of density. Density
may be determined by multiplying the bulk specific gravity, bulk specific gravity (SSD), or
apparent specific gravity by the density of water (997.5 kg/m³ or 0.9975 Mg/m³ or 62.27 lb/ft³
at 23°C). Some authorities recommend using the density of water at 4°C (1000 kg/m³ or
1.000 Mg/m³ or 62.43 lb/ft³) as being sufficiently accurate. The density terminology corresponding to bulk specific gravity, bulk specific gravity (SSD), and apparent specific gravity has not been standardized.

9.3. **Absorption**—Calculate the percentage of absorption, as follows:

\[
\text{absorption, percent} = \left( \frac{B - A}{A} \right) \times 100
\]

(5)

9.4. **Average Absorption Value**—When the sample is tested in separate size fractions, the average absorption value is the average of the values as computed in Section 9.3, weighted in proportion to the mass percentages of the size fractions in the original sample as follows:

\[
A = \left( P_1 A_1 / 100 \right) + \left( P_2 A_2 / 100 \right) + \cdots + \left( P_n A_n / 100 \right)
\]

(6)

where:

- \( A \) = average absorption, percent;
- \( P_1, P_2, \ldots, P_n \) = mass percentages of each size fraction present in the original sample; and
- \( A_1, A_2, \ldots, A_n \) = absorption percentages for each size fraction.

10. **REPORT**

10.1. Report specific gravity results to the nearest 0.001 (Coarse Aggregate meeting M 80 requirements may be reported to the nearest 0.01), and indicate the type of specific gravity, whether bulk, bulk (SSD), or apparent.

10.2. Report the absorption result to the nearest 0.1 percent.

10.3. If the specific gravity and absorption values were determined without first drying the aggregate, as permitted in Section 8.2, it shall be noted in the report.

11. **PRECISION AND BIAS**

11.1. The estimates of precision of this test method listed in Table 1 are based on results from the AASHTO Materials Reference Laboratory Reference Sample Program, with testing conducted by this test method and ASTM C127. The significant difference between the methods is that ASTM C127 requires a saturation period of 24 ± 4 h, while T 85 requires a saturation period of 15 to 19 h. This difference has been found to have insignificant effect on the precision indices. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories.
<table>
<thead>
<tr>
<th></th>
<th>Standard Deviation (1s)&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Acceptable Range of Two Results (d2s)&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single-operator precision:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulk specific gravity (dry)</td>
<td>0.009</td>
<td>0.025</td>
</tr>
<tr>
<td>Bulk specific gravity (SSD)</td>
<td>0.007</td>
<td>0.020</td>
</tr>
<tr>
<td>Apparent specific gravity</td>
<td>0.007</td>
<td>0.020</td>
</tr>
<tr>
<td>Absorption, percent</td>
<td>0.088</td>
<td>0.25</td>
</tr>
<tr>
<td><strong>Multilaboratory precision:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulk specific gravity (dry)</td>
<td>0.013</td>
<td>0.038</td>
</tr>
<tr>
<td>Bulk specific gravity (SSD)</td>
<td>0.011</td>
<td>0.032</td>
</tr>
<tr>
<td>Apparent specific gravity</td>
<td>0.011</td>
<td>0.032</td>
</tr>
<tr>
<td>Absorption, percent</td>
<td>0.145</td>
<td>0.41</td>
</tr>
</tbody>
</table>

<sup>a</sup> These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM C670. The precision estimates were obtained from the analysis of combined AASHTO Materials Reference Laboratory reference sample data from laboratories using 15-h minimum saturation times and other laboratories using 24 ± 4-h saturation time. Testing was performed on aggregates of normal specific gravities and started with aggregates in the oven-dry condition.

<sup>b</sup> Precision estimates are based on aggregates with absorptions of less than 2 percent.

### 11.2. Bias

Because there is no accepted reference material for determining the bias for the procedure in this test method, no statement on bias is being made.

### 12. KEYWORDS

12.1. Absorption; coarse aggregate; saturated surface-dry (SSD); specific gravity.

### APPENDIXES

(Nonmandatory Information)

#### X1. DEVELOPMENT OF EQUATIONS

**X1.1.**

The derivation of the equation is apparent from the following simplified cases using two solids. Solid 1 has a mass $W_1$ in grams and a volume $V_1$ in milliliters; its specific gravity ($G_1$) is therefore $W_1/V_1$. Solid 2 has a mass $W_2$ and volume $V_2$, and $G_2 = W_2/V_2$. If the two solids are considered together, the specific gravity of the combination is the total mass in grams divided by the total volume in milliliters:

$$
G = \frac{W_1 + W_2}{V_1 + V_2}
$$

**Equation (X1.1)**

Manipulation of this equation yields the following:

$$
G = \frac{1}{V_1 + V_2} \left( \frac{V_1}{W_1 + W_2} + \frac{V_2}{W_1 + W_2} \right)
$$

**Equation (X1.2)**

$$
G = \frac{1}{W_1 + W_2} \left( \frac{W_1}{V_1} + \frac{W_2}{V_2} \right)
$$

**Equation (X1.3)**
However, the mass fractions of the two solids are:

\[
\frac{W_1}{(W_1 + W_2)} = \frac{P_1}{100}
\]  
(\text{XI.4})

and:

\[
\frac{W_2}{(W_1 + W_2)} = \frac{P_2}{100}
\]  
(\text{XI.5})

and:

\[
\frac{1}{G_1} = \frac{V_1}{W_1} \text{ and } \frac{1}{G_2} = \frac{V_2}{W_2}
\]  
(\text{XI.6})

therefore:

\[
G = \left(\frac{P_1}{100}\right)\left(\frac{1}{G_1}\right) + \left(\frac{P_2}{100}\right)\left(\frac{1}{G_2}\right)
\]  
(\text{XI.7})

An example of the computation is given in Table X1.1.

\begin{table}
\centering
\begin{tabular}{lllll}
\hline
Size Fraction, mm (in.) & Percent in Original Sample & Bulk Specific Gravity (SSD) & Sample Mass Used in Test, g & Absorption, % \\
\hline
4.75 to 12.5 (No. 4 to 1/2) & 44 & 2.72 & 2213.0 & 0.4 \\
12.5 to 37.5 (1/2 to 1/2) & 35 & 2.56 & 5462.5 & 2.5 \\
37.5 to 63 (1 to 2/1) & 21 & 2.54 & 12593.0 & 3.0 \\
\hline
\end{tabular}
\caption{Example Calculation of Average Values of Specific Gravity and Absorption for a Coarse Aggregate Tested in Separate Sizes}
\end{table}

\(a\) Average specific gravity (SSD)

\[
G_{\text{SSD}} = \frac{1}{2.72 + 2.56 + 2.54} = 2.62
\]  
(XI.8)

Average absorption:

\[
A = (0.44)(0.4) + (0.35)(2.5) + (0.21)(3.0) = 1.7\%
\]  
(XI.9)

\section*{X2. INTERRELATIONSHIPS BETWEEN SPECIFIC GRAVITIES AND ABSORPTION AS DEFINED IN METHODS T 85 AND T 84}

\subsection*{X2.1.}

Let:

\begin{align*}
S_d &= \text{bulk specific gravity (dry basis)}, \\
S_s &= \text{bulk specific gravity (SSD basis)}, \\
S_a &= \text{apparent specific gravity, and} \\
A &= \text{absorption in percent.}
\end{align*}
Then:

\[
S_s = \left( 1 + \frac{A}{100} \right) S_d 
\]

\[\text{(X2.1)}\]

\[
S_d = \frac{1 - \frac{A}{100}}{1 + \frac{A}{100}} S_d = \frac{S_d}{1 + \frac{A}{100} S_d} 
\]

\[\text{(X2.2)}\]

\[
S_s = \frac{1}{1 + \frac{A}{100}} \frac{A}{100} 
\]

\[\text{(X2.3)}\]

\[
A = \left( \frac{S_s}{S_d} - 1 \right) 100 
\]

\[\text{(X2.4)}\]

\[
A = \left( \frac{S_s - S_d}{S_s (S_s - 1)} \right) 100 
\]

\[\text{(X2.5)}\]

\(^1\text{This method is technically equivalent to ASTM C127-12.}\)
Standard Method of Test for

Quantitative Extraction of Asphalt Binder from Hot Mix Asphalt (HMA)

AASHTO Designation: T 164-14 (2018)¹
Technical Section: 2c, Asphalt–Aggregate Mixtures
Release: Group 3 (August)
ASTM Designation: D2172/D2172M-11
Standard Method of Test for

Quantitative Extraction of Asphalt Binder from Hot Mix Asphalt (HMA)

AASHTO Designation: T 164-14 (2018)¹

Technical Section: 2c, Asphalt–Aggregate Mixtures

Release: Group 3 (August)

ASTM Designation: D2172/D2172M-11

1. SCOPE

1.1. These methods cover the quantitative determination of asphalt binder in hot mix asphalt (HMA) and HMA pavement samples. Aggregate obtained by these methods may be used for sieve analysis using T 30.

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

1.3. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns 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. Specific hazards are given in Section 8.

Note 1—The results obtained by these methods may be affected by the age of the material tested, with older samples tending to yield slightly lower asphalt binder contents. Best quantitative results are obtained when the test is made on HMA mixtures and pavements shortly after their preparation. It is difficult to remove all the asphalt binder when some aggregates are used; some solvent may remain within the mineral matter affecting the measured asphalt binder content.

2. REFERENCED DOCUMENTS

2.1. AASHTO Standards:
- M 231, Weighing Devices Used in the Testing of Materials
- R 59, Recovery of Asphalt Binder from Solution by Abson Method
- T 30, Mechanical Analysis of Extracted Aggregate
- T 84, Specific Gravity and Absorption of Fine Aggregate
- T 110, Moisture or Volatile Distillates in Hot Mix Asphalt (HMA)
- T 168, Sampling Bituminous Paving Mixtures
- T 228, Specific Gravity of Semi-Solid Asphalt Materials
- T 329, Moisture Content of Asphalt Mixtures by Oven Method

2.2. ASTM Standards:
- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
2.3. **Federal Standard:**


3. **TERMINOLOGY**

3.1. *nominal maximum size (of aggregate)—* one size larger than the first sieve that retains more than 10 percent aggregate.

3.2. *constant mass—* shall be defined as the mass at which further drying does not alter the mass by more than 0.05 percent when weighed at 2-h intervals.

4. **SUMMARY OF TEST METHODS**

4.1. The HMA is extracted with trichloroethylene, *n*-propyl bromide, or methylene chloride, using the extraction equipment applicable to the particular method. Terpene extractant may be used in Method A or E. The asphalt binder content is calculated by differences from the mass of the extracted aggregate, moisture content, and mineral matter in the extract. The asphalt binder content is expressed as a mass percent of moisture-free mixtures.

5. **SIGNIFICANCE AND USE**

5.1. All of the methods can be used for quantitative determinations of asphalt binder in HMA mixtures and pavement samples for specification acceptance, service evaluation, quality control, and research. Each method prescribes the solvents and any other reagents that can be used in the method. R 59 requires that Method A or E (Note 2) and reagent-grade trichloroethylene be used when asphalt binder is recovered from solution.

   **Note 2**—The vacuum extractor, Section 22.1.1, can be modified by a vacuum trap attached to the top of the "end point" sight tube to collect the extract to allow its use for recoveries (Figure 4b).

6. **APPARATUS**

6.1. *Oven—* Capable of maintaining the temperature at 110 ± 5°C (230 ± 9°F), for warming the sample.

6.2. *Oven—* Capable of maintaining the temperature at 149 to 163°C (300 to 325°F), for drying the sample if the moisture content is not determined.

6.3. *Pan—* Flat, of appropriate size.

6.4. *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.
6.5. **Cylinders**—Graduated, 1000- or 2000-mL capacity.

7. **REAGENTS**


7.2. *n-Propyl Bromide*—Conforming to ASTM D6368—see Section 8.

7.3. *Trichloroethylene*—Reagent grade (Note 3) or conforming to ASTM D4080—see Section 8.

7.4. *Terpene*—Extractant, shall be nonhalogenated, nontoxic, and shall readily dissolve asphalt binder from HMA and place it into solution. This extractant shall be easily rinsed from the remaining aggregate without forming a gel, and the extractant rinsed from the aggregate shall pass readily through the diatomaceous earth and the filter.

7.5. When asphalt binder is intended to be extracted and then tested for additional properties, a reagent-grade solvent must be used (Note 3).

**Note 3**—Non-reagent-grade solvents may contain epoxy resins that may affect the properties of the recovered binder. In particular, certain acid modified binders may be affected by non-reagent-grade solvents.

**Note 4**—Only vented ovens should be used when terpene extractants are used.

8. **PRECAUTIONS**

8.1. The solvents listed in Section 7 should be used only under a hood or with an effective surface exhaust system in a well-ventilated area, because they are all toxic to some degree, as described in OSHA 1910.1200. Trichloroethylene, methylene chloride, and *n*-propyl bromide in the presence of heat and moisture may form acids that are extremely corrosive to certain metals, particularly when subject to contact over lengthy periods of time. Proper precautions should be taken to not allow these solvents to remain in small quantities in the effluent tanks of aluminum vacuum extractors.

8.2. Trichloroethylene stored in a steel container and in continuous contact with moisture may decompose by dehydrohalogenation to form unsaturated hydrocarbon liquids and hydrogen chloride. Steel drums containing trichloroethylene should be stored in a cool, dry location, kept tightly sealed, and opened as infrequently as possible. Trichloroethylene should be transferred from the drums to clean, dry, brown glass bottles for laboratory use. The hydrogen chloride in decomposed trichloroethylene may harden an asphalt during the extraction and Abson recovery test (R 59).

8.3. All local, state, and federal regulations must be followed when hauling, using, storing, and discarding extractants and rinse water. These requirements include fire ordinances as well as wastewater treatment regulations. The Material Safety Data Sheet should be followed closely to avoid fires and explosions. Storage of extractant-soaked rags should be prohibited.

9. **SAMPLING**

9.1. Obtain samples in accordance with T 168.

9.2. *Preparation of Test Specimens*:
9.2.1. If the HMA is not sufficiently soft to separate with a spatula or trowel, place it in a large, flat pan, and warm it in a 110 ± 5°C (230 ± 9°F) oven only until it can be handled or separated. Split or quarter the material until the mass of material required for the test is obtained.

9.2.2. The size of the test sample shall be governed by the nominal maximum aggregate size of the HMA and conform to the mass requirement shown in Table 1 (Note 5).

Table 1—Size of Sample

<table>
<thead>
<tr>
<th>Nominal Maximum Aggregate Size</th>
<th>Minimum Mass of Sample, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>in.</td>
</tr>
<tr>
<td>4.75 200 mesh</td>
<td>No. 4</td>
</tr>
<tr>
<td>9.5 1/8 in.</td>
<td></td>
</tr>
<tr>
<td>12.5 1/2 in.</td>
<td></td>
</tr>
<tr>
<td>19.0 3/4 in.</td>
<td></td>
</tr>
<tr>
<td>25.0 1 in.</td>
<td></td>
</tr>
<tr>
<td>37.5 1 1/2 in.</td>
<td></td>
</tr>
</tbody>
</table>

Note 5—When the mass of the test specimen exceeds the capacity of the equipment used (for a particular method), the test specimen may be divided into suitable increments, tested, and the results appropriately combined for calculation of asphalt binder content (Section 13).

9.2.3. Unless the HMA sample is free of moisture (Note 7), a test specimen is required for the determination of moisture (Section 10) in the HMA. Take this test specimen from the remaining sample in the HMA immediately after obtaining the extraction test specimen.

Note 6—If the extraction test is being performed only to recover asphalt binder from the HMA and the percent asphalt binder is not being determined, it is unnecessary to determine the moisture content of the HMA.

Table 2—Dimensional Equivalents

<table>
<thead>
<tr>
<th>mm</th>
<th>1/32</th>
<th>in.</th>
<th>mm</th>
<th>1/32</th>
<th>in.</th>
<th>mm</th>
<th>1/32</th>
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<td>1.03</td>
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</table>
10. **MOISTURE CONTENT**

10.1. When required, determine the moisture content of the mixture (Section 9.2.3) in accordance with the procedure described in T 110 or T 329.

**Note 7**—If recovery of asphalt binder from the solution obtained from the extraction test is not required, the entire test specimen may be dried in an oven at a temperature of 105 to 165°C (221 to 329°F) to constant mass prior to extraction, instead of determining the moisture content.

10.2. Calculate the mass of water \( W_2 \) (Section 13) in the extraction test portion by multiplying mass percent water (Section 10.1) by the mass of the extraction test portion \( W_1 \) (Section 13).

## TEST METHOD A

11. **APPARATUS**

11.1. In addition to the apparatus listed in Section 6, the following apparatus is required for Method A:

11.1.1. **Extraction Apparatus**—Consisting of a bowl approximating that shown in Figure 1 and an apparatus in which the bowl may be revolved at controlled variable speeds up to 3600 r/min. The speed may be controlled manually or with a preset speed control. The apparatus should be provided with a container for catching the solvent discharged from the bowl and a drain for removing the solvent. The apparatus preferably shall be provided with explosion-proof features and installed in a hood or an effective surface exhaust system to provide ventilation.

**Note 8**—Similar apparatus of larger size may be used.

11.1.2. **Filter Rings**—Felt or paper, to fit the rim of the bowl.

11.1.3. **Low-Ash Paper Filter Rings**—May be used in place of the felt filter ring (Section 11.1.2). Such filter rings shall consist of low-ash filter paper stock, 1.27 ± 0.13 mm (0.05 ± 0.005 in.) thick. The nominal base weight of the paper shall be 150 ± 14 kg (330 ± 30 lb) for a ream [500 sheets, 635 by 965 mm (25 by 38 in.)]. The ash content of the paper should not exceed 0.2 percent (approximately 0.034 g per ring).

**Note 9**—Where terpene extractants are used, the gears and shaft should be lubricated frequently.
12. **PROCEDURE**

12.1. Determine the moisture content of the material in accordance with Section 10.

12.2. Place the test portion into a bowl.

12.3. Cover the test portion in the bowl with trichloroethylene, methylene chloride, *n*-propyl bromide, or terpene extractant, and allow sufficient time for the solvent to disintegrate the test portion (not more than 1 h). Place the bowl containing the test portion and the solvent in the extraction apparatus. Dry the filter ring to a constant mass in an oven at 110 ± 5°C (230 ± 9°F), and fit it around the edge of the bowl. Clamp the cover on the bowl tightly, and place an appropriate container under the drain to collect the extract.

12.4. Start the centrifuge revolving slowly, and gradually increase the speed to a maximum of 3600 r/min until the solvent ceases to flow from the drain. Allow the machine to stop; add 200 mL (or more as appropriate for the mass of the sample) of trichloroethylene, methylene chloride, *n*-propyl bromide, or terpene extractant, and repeat the procedure. Use sufficient solvent additions (not less than three) until the extract is not darker than a light straw color (when viewed against a white background). Collect the extract and the washings in an appropriate container for mineral matter determination.
12.5. Carefully transfer the filter ring and all of the aggregate in the centrifuge bowl into a tared metal pan. Dry in air under a hood until the fumes dissipate, and then to a constant mass in an oven at 110 ± 5°C (230 ± 9°F) (Notes 10 and 11). The mass of the extracted aggregate \( W_3 \) is equal to the mass of the contents in the pan minus the initial dry mass of the filter ring. Brush off mineral matter adhering to the surface of the filter ring, and add it to the extracted aggregate for further testing.

**Note 10**—The filter and aggregate may be left inside the centrifuge bowl and dried to constant mass in an oven at 110 ± 5°C (230 ± 9°F) and the mass determined.

**Note 11**—The filter ring may be dried separately to constant mass in an oven at 110 ± 5°C (230 ± 9°F) provided that care is taken not to lose any of the fine material clinging to the filter. If this procedure is used, the aggregate may then be dried to constant mass either in an oven or on a hot plate at 110 ± 5°C (230 ± 9°F).

12.5.1. Use the following alternative procedure when low-ash filter rings are used. Place the aggregate and filter rings in a clean metal pan. Dry as specified above. Carefully fold the dried filter ring and stand it on the aggregate. Burn the filter ring. Determine the mass of the extracted aggregate in the pan \( W_3 \).

**Note 12**—Because dry aggregate absorbs moisture when exposed to air containing moisture, determine the mass of the extracted aggregate immediately after cooling to a suitable temperature.

12.6. Determine the amount of mineral matter in the extract by one of the procedures specified in Annex A1.

### 13. CALCULATION OF ASPHALT BINDER CONTENT

\[
\text{asphalt binder content, } \% = \frac{W_1 - W_2 - (W_3 + W_4)}{W_1 - W_2} \times 100 \tag{1}
\]

where:
- \( W_1 \) = mass of test portion;
- \( W_2 \) = mass of water in test portion;
- \( W_3 \) = mass of extracted mineral aggregate; and
- \( W_4 \) = mass of mineral matter in the extract.

**Note 13**—When ashless filter rings are not used, add the increase in mass of the felt ring to \( W_4 \).

**Note 14**—When it is desired to express the asphalt binder content as a mass percent of the moisture-free aggregate, substitute the mass \( W_3 + W_4 \) for the mass \( W_1 - W_2 \) in the divisor of Equation 1.

### TEST METHOD B

#### 14. APPARATUS

14.1. In addition to the apparatus listed in Section 6, the following apparatus is required for Test Method B:

14.1.1. *Extraction Apparatus*—Similar to that shown in Figure 2.
14.1.1.1. *Glass Jar*—Cylindrical, plain, made of heat-resistant glass. The jar shall be free of cracks, scratches, or other evidence of flaws that might cause breakage during heating.

14.1.1.2. *Cylindrical Metal Frames*—One or two. The lower frame shall have legs of sufficient length to support the frame, including the apex of the metal cone and paper cone liner above the solvent level. When two frames are used, the upper frame shall have legs of sufficient length to support the metal cone and paper cone liner at or above the top rim of the lower frame. The legs of the upper frame shall fit securely in the top rim of the lower frame. A bail handle may be provided on the inside of the top rim of each frame for convenient handling. The metal used in fabricating the frames shall be essentially unreactive to the solvents used in the test.

14.1.1.3. *Condenser*—Fabricated with a truncated hemispherical condensing surface and a truncated conical top. Other suitable geometric shapes may also be used, provided they accomplish the condensing and flow functions intended. The material used in fabricating the condenser shall be essentially unreactive to water and to the solvent used and shall be provided with a suitable water inlet and outlet.

14.1.1.4. *Filter Paper*—Medium-grade, fast-filtering. The diameter of the paper shall be such that when folded in accordance with the directions given below, it shall completely line the metal cones in the frames.

14.1.1.5. *Thermal Distributing Protective Pad*—Approximately 3 mm (0.1 in.) thick for use as insulation between the glass jar and hot plates.

14.1.1.6. *Electric Hot Plate*—Thermostatically controlled, of sufficient dimensions and heat capacity to permit refluxing of the solvent as described in Section 16.2.5.
15. PREPARATION OF TEST PORTION

15.1. Prepare a test portion for moisture determination and extraction in accordance with the procedure described in Section 9.

16. PROCEDURE

16.1. Moisture:

16.1.1. Determine the moisture content of the HMA (Section 9.2.3) in accordance with the method described in Section 10.

16.2. Extraction:

16.2.1. Dry one sheet of filter paper for each frame used to a constant mass in an oven at 110 ± 5°C (230 ± 9°F). Fold each paper on its diameter; fold the ends over, and spread it open to form a proper size to fit inside the metal cones.

16.2.2. Determine the mass of each frame with its filter paper liner to the nearest 0.5 g. Record the mass of each frame.

16.2.3. Place the test portion in the frame(s). If two frames are used, distribute the test portion approximately equally between the two. The top of the test portion must be below the upper edge of the paper liner. Determine the mass of each loaded frame separately to the nearest 0.5 g. Again, record the mass.

16.2.4. Use one of the solvents (Note 15) specified in Section 7.1, 7.2, or 7.3. Pour the solvent into the glass cylinder, and place the bottom frame into it. The solvent level should be below the apex of the one in the lower frame. If two frames are used, place the upper frame in the lower frame, fitting its legs into the holes in the upper rim of the lower frame.

Note 15—Sufficient denatured ethyl alcohol may be poured over the test portion(s) to wet the filter paper. A mixture of 20 percent denatured alcohol and 80 percent trichloroethylene has proven to be a better solvent for some aggregates.

16.2.5. If required, place the thermal insulating pad on the hot plate and then the cylinder on the pad. Cover the condenser. Circulate a gentle, steady stream of cool water through the condenser. Adjust the temperature of the hot plate so that the solvent will boil gently and a steady stream of condensed solvent flows into the cone. If necessary, adjust the temperature of the hot plate to maintain the solvent stream at a rate necessary to keep the test portions in the cone(s) completely covered with condensed solvent. Take care not to allow condensed solvent to overflow the filter cone(s). Continue the refluxing until the solvent flowing from the lower cone is a light straw color (when viewed against a white background). At this point, turn off the hot plate and allow the apparatus to cool enough to handle; turn off the condenser and remove it from the cylinder.

16.2.6. Remove the frame assembly from the cylinder. Allow it to dry in air (hood), and then dry it to a constant mass in an oven at 110 ± 5°C (230 ± 9°F) (Note 9).

16.2.7. Determine the mineral matter in the extraction solution by one of the procedures specified in Annex A1.
17. **CALCULATION OF ASPHALT BINDER CONTENT**

17.1. Calculate the percentage of asphalt binder in the test portion in accordance with the procedure described in Section 13.

**TEST METHOD D**

18. **APPARATUS**

18.1. In addition to the apparatus listed in Section 6, the following apparatus is required for Test Method D:

18.1.1. *Extraction Apparatus*—As shown in Figure 3, consisting of an extraction kettle of metal or borosilicate glass, fitted with a perforated basket and a condenser top. The underside of the condenser shall be covered with numerous rounded knobs to distribute the condenser solvent uniformly over the surface of the sample. The suspension of the basket shall be arranged to support the basket 13 mm (1/2 in.) above the bottom of the kettle, for immersion of the test portion in the solvent, and at least 75 mm (3 in.) above the bottom of the kettle for refluxing (Note 8).

18.1.2. *Cloth Filter Sacks*—With an elastic hem for lining the basket.

![Figure 3—Extractor Unit (Method D)](image-url)
19. PREPARATION OF TEST PORTIONS

19.1. Prepare test portions for moisture determination and extraction in accordance with the procedure described in Section 9.

20. PROCEDURE

20.1. Moisture:

20.1.1. Determine the moisture content of the HMA (Section 9.2.3) in accordance with the method described in Section 10.

20.2. Extraction:

20.2.1. Insert a filter sack in the extraction basket, and determine the mass with the tare pan to determine the total tare mass. Place the test portion in the filter sack, and determine the total mass. Calculate the mass of the test portion.

20.2.2. Attach the suspension rod to the loaded basket, and set the assembly into the extraction kettle. Pour approximately 600 mL of solvent (Section 7.1, 7.2, or 7.3) over the test portion. Set the condenser cover in place on the kettle. Provide a flow of cold water through the condenser lid. Raise the basket to immersion level—for example 13 mm (1/2 in.) above the bottom of the kettle—by inserting the support pin through the upper hole of the suspension rod. Place the extractor on the hot plate and adjust the heating rate so that the solvent is maintained at a gentle boil, avoiding vigorous boiling, which might wash fines over the sides of the basket.

20.2.3. Continue heating with the test portion in the immersion position for 15 to 30 min, and then raise the basket to refluxing level. Increase the heat, and maintain active boiling until the solvent dripping from the basket appears to be a light straw color when viewed against a white background. If a stainless steel kettle is used, lift out the basket and the condenser cover assembly for examination of the solvent.

20.2.4. Remove the extractor from the hot plate, and allow it to cool for several minutes. Lift out the basket and condenser assembly. Cover the kettle; remove the filter sack, and distribute its contents into the tared pan in which the mass of the test portion was originally determined. Place the filter sack on top of the recovered aggregate. Dry on a steam bath and then in an oven at 110 ± 5°C (230 ± 9°F) to constant mass. Transfer the extract solution to a 1000-mL graduate. Wash the extractor clean with solvent, and add the washings to the extract solution.

20.2.5. Determine the mineral matter in the extract solution by one of the procedures specified in Annex A1.

21. CALCULATION OF ASPHALT BINDER CONTENT

21.1. Calculate the percentage of asphalt binder in the test portion in accordance with the procedure described in Section 13.
TEST METHOD E

22. APPARATUS

22.1. In addition to the apparatus listed in Section 6, the following apparatus is required for Test Method E:

22.1.1. *Vacuum Extractor*—Complete with the vacuum pump, gasket, rubber tubing, filter paper, support plate, and funnel ring. The dimensional equivalents and apparatus shown in Table 3, and Figures 4a, 4b, and 4c and similar designs, are suitable.

**Table 3—Dimensional Equivalents**

<table>
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<th>in.</th>
<th>mm</th>
<th>in.</th>
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</tr>
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</table>
Figure 4a — Vacuum Extractor

Note: See Table 3 for dimensional equivalents. All dimensions shown in millimeters unless otherwise noted.
Figure 4b—Vacuum Extractor

Note: All dimensions are shown in millimeters unless otherwise noted.
22.1.2. *Filter Paper*—Medium-grade, fast-filtering, 330 mm (13 in.) in diameter.

22.1.3. *Sample Container*—3.8-L (4-qt) capacity or greater.

22.1.4. *Erlenmeyer Flasks*—Glass, two, having a capacity of 4000 mL each.

22.1.5. *Graduated Cylinder*—Glass, having a capacity of 500 mL.

22.1.6. *Wash Bottle*—Plastic, having a capacity of 500 mL.

22.1.7. *Dial Thermometer*—Having a range from 10 to 82°C (50 to 180°F).

22.1.8. *Mixing Spoon*.

22.1.9. *Spatula*.

22.1.10. *Stiff Bristled Brush*.

22.1.11. *Erlenmeyer Flask*—Glass, having a capacity of 1000 mL.
22.1.12. *Watch Glass*—Having a diameter of approximately 100 mm (4 in.).

22.1.13. *Metal Tongs*—150 to 200 mm (6 to 8 in.) long.

22.1.14. *Sieves*—1.18-mm (No. 16) and 75-µm (No. 200), 305 mm (12 in.) in diameter (optional).

**Note 16**—Use apparatus and materials listed under Sections 22.1.11, 22.1.12, 22.1.13, 23.1, and 23.2 only with HMA that is hard to filter, as in Method E-II.

22.1.15. *Stainless Steel Beaker*.

23. **REAGENTS AND MATERIALS**

23.1. *Diatomaceous Silica Filtering Aid*—Conforming to Type B of ASTM D604.

23.2. *Ethyl Alcohol*—Denatured (optional).

23.3. *Methylene Chloride* (Note 17).

**Note 17**—Any of the other solvents listed in Section 7 may be substituted for methylene chloride.

24. **PREPARATION OF TEST PORTIONS**

24.1. Prepare test portions for moisture determination and extraction in accordance with the procedure described in Section 9.

25. **PROCEDURE**

25.1. Determine the moisture content of the HMA (Section 9.2.3) in accordance with the method described in Section 10.

25.2. *Extraction*:

25.2.1. Place the extraction test portion into the tared stainless steel beaker, and determine the mass (Note 18).

25.2.2. If the test portion is above 54°C (130°F), allow it to cool to a temperature less than 54°C (130°F). When sufficiently cool, pour 200 mL of denatured alcohol, if needed, over the specimen (Note 18). Add approximately 700 mL of extractant, and stir until the asphalt binder is visually in solution (Note 19).

**Note 18**—Alcohol should not be needed with terpene extractants.

**Note 19**—If equipment is available, an ultrasonic cleaning tank may be used instead of the beaker (Section 25.2.1) in which to bring the asphalt binder into solution (Section 25.2.2).

**METHOD E-I**

25.2.3. Dry the filter paper (more than one filter paper may be used) to constant mass in an oven at 110 ± 5°C (230 ± 9°F), and place the filter paper on the extractor, taking care to center the filter paper and tighten the wing nuts “finger tight” (Note 20).

**Note 20**—Experience has shown that clogging of the filter may be reduced by decanting the extract solution through nested 1.18-mm (No. 16) and 75-µm (No. 200) sieves onto the filter.
When sieves are used, the solution will be decanted onto the 1.18-mm (No. 16) sieve instead of
the filter.

25.2.4. Start the vacuum pump and slowly decant extract solution from the sample container onto the
filter. When all solution has been removed from the filter paper, the vacuum pump may be stopped
or left running.

25.2.5. Cover the sample remaining in the container with extractant, up to 700 mL. Stir gently until the
asphalt binder and aggregate fines appear to be in suspension (or start the ultrasonic cleaner if
used). Repeat the step in Section 25.2.4.

25.2.6. Repeat Section 25.2.5 until the solution is a light straw color (when viewed against a white
background) and the aggregate is visually clean. The flow of solvent may be slowed for color
observation by partially opening the vacuum valve and reducing the vacuum. If terpene extractant
is used, pour all of the extractant onto the filter, and allow the vacuum to continue until the fluid
has passed through the filter. Repeat Sections 25.2.5 and 25.2.4, using water preferably above
43°C (110°F), as many times as necessary to remove the terpene residue from the aggregate and
render the rinse water clear. Operate the vacuum pump for a few minutes after the last wash to aid
in drying the test portion. Scrape the aggregate away from the side of the funnel ring toward the
center of the filter to avoid loss when the ring is removed. Also wash the sides of the funnel ring to
remove any fines. Stop the vacuum pump and remove the ring, then brush the clinging aggregate
into the tared drying pan. Carefully pick up the filter paper and aggregate by holding the paper on
opposite sides and raising it straight up. Transfer the aggregate on the filter paper to the tared
drying pan, and brush the clinging aggregate from the filter into the pan. Alternatively, the filter
paper and aggregate may be contained separately in tared pans or the aggregate may be contained
in a tared pan and the filter paper placed on top of it. In either case, use care to assure that all
traces of aggregate in the test sample are transferred to the drying pan(s).

25.2.7. Dry the extracted aggregate and filter to a constant mass in an oven at 110 ± 5°C (230 ± 9°F)
(Note 21).

**Note 21**—See the alternate procedure in Section 12.5.1 when low-ash filter paper is used.

25.2.8. Determine the mass of the filter and aggregate in the pan(s), and record it. Subtract the mass of the
filter and pan to determine the mass of the extracted aggregate.

25.2.9. Determine the mineral matter in the extract solution by one of the procedures specified in
Annex A1 (Note 22).

**Note 22**—Sections 25.2.9 and 25.2.15 may be omitted when this method is used only for control
of asphalt binder content during HMA production (plant control).

**METHOD E-II**

25.2.10. To extract a slow-filtering HMA mixture efficiently, prepare the test portion as described in
Sections 25.2.1 and 25.2.2.

25.2.11. Dry the filter paper to constant mass in an oven at 110 ± 5°C (230 ± 9°F), and place the filter
paper on the extractor, taking care to center the filter paper and tighten the wing nuts “finger tight”
(Note 20).

25.2.12. Weigh between 50 and 200 g of oven-dried diatomaceous silica filtering aid into a 1000-mL
Erlenmeyer flask; record the mass, and then add 500 mL of extractant. Swirl until the
diatomaceous silica is completely in suspension.
25.2.13. Immediately pour the diatomaceous silica and extractant over the filter. Two predried filters separated by an additional 50 to 100 g of diatomaceous earth may be used to retain the minus 75-µm (No. 200) material, if desired, to facilitate improved flow of the liquid. Start the vacuum pump, and let it run until the pad formed by the diatomaceous silica is surface dry and begins to crack slightly (Note 23).

Note 23—Some diatomaceous silica may be washed through the filter and included in the mineral matter determination of Section 25.2.15. Blank tests are recommended to determine the amount of diatomaceous silica, if any, lost through the filter. An appropriate correction will be required in the mineral matter mass.

25.2.14. Place the watch glass in the extractor, and slowly decant the extractant from the container over the watch glass (Note 24). Stop the vacuum pump when all the solution has been removed from the filter. Repeat as in Section 25.2.5, except decant the solution onto the watch glass. Complete the procedure as in Section 25.2.6. Also wash the watch glass with extractant to remove any fines onto the filter.

Note 24—When nested sieves are used, the watch glass may be omitted.

25.2.15. Determine the amount of mineral matter in the extract solution by one of the procedures specified in Annex A1 (Note 22).

26. CALCULATION OF ASPHALT BINDER CONTENT (APPLICABLE TO BOTH METHOD E-I AND METHOD E-II)

26.1. Calculate the percentage of asphalt binder in the test portion in accordance with the procedure described in Section 13.

27. PRECISION AND BIAS

27.1. The single-laboratory standard deviation has been found to be 0.18 percent. Therefore, results of two properly conducted tests by the same operator on the same batch should not differ by more than 0.52 percent. These values become 0.21 and 0.58, respectively, when extractant containing 85 percent terpene is used (Notes 25 and 26).

27.2. The multilaboratory standard deviation has been found to be 0.29 percent. Therefore, the results of two properly conducted tests from two different laboratories on samples from the same batch should not differ by more than 0.81 percent. These values become 0.29 and 0.83, respectively, when extractant containing 85 percent terpene is used (Notes 25 and 26).

Note 25—These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM C670.

Note 26—These precision statements are based on one pair of reference samples with 59 laboratories participating and three laboratory results deleted as outlying observations. The reference samples contained aggregate with 98 percent passing the 9.5-mm (3/8-in.) screen. All test methods were used in the interlaboratory test program.

28. KEYWORDS

28.1. Asphalt binder; asphalt mixture; asphalt mixture extraction; centrifuge; hot mix asphalt; mineral matter; reflux; solvent; vacuum extraction.
**ANNEX A**

(Mandatory Information)

**A1. DETERMINING THE AMOUNT OF MINERAL MATTER IN THE EXTRACT**

**A1.1. Ashing Method:**

**A1.1.1. Apparatus:**

A1.1.1.1. *Ignition Dish*—At least 125 mL in capacity.

A1.1.1.2. Ignition Furnace or Bunsen Burner.

A1.1.1.3. Steam Bath or Hot Plate.

A1.1.1.4. Desiccator.

A1.1.1.5. *Analytical Balance*—Conforming to the requirements of M 231, Class B.

A1.1.1.6. *Cylinder*—100 mL in capacity.

**A1.1.2. Reagents:**

A1.1.2.1. *Ammonium Carbonate Solution*—Saturated solution of reagent-grade ammonium carbonate [(NH₄)₂CO₃].

**A1.1.3. Procedure:**

A1.1.3.1. Determine either the volume or mass of the total extract (W₁). Condition the ignition dish in an ignition furnace or over a Bunsen burner at a dull red heat for a minimum of 10 min; cool it in a desiccator, and determine the mass of the ignition dish to the nearest 0.001 g. Agitate the extract thoroughly, and immediately measure 100 mL or 100 g into the ignition dish. Evaporate to dryness on a steam bath or hot plate. Ash the residue at a dull red heat (500 to 600°C [932 to 1112°F]) and cool it. Determine the mass of the ash, and add 5 mL of saturated ammonium carbonate solution per gram of ash. Digest at room temperature for 1 h. Dry in an oven at 110 ± 5°C (230 ± 9°F) to constant mass; cool in a desiccator, and determine the mass to the nearest 0.001 g (G). Calculate the mass of mineral matter in the total volume of extract (W₄) as follows:

\[ W₄ = G \left( \frac{W₁}{100} \right) \]  

where:

\[ G \] = ash remaining in the ignition dish to nearest 0.001 g; and  
\[ W₁ \] = total volume, mL (or total mass, g) of extract.

**A1.2. Centrifuge Method:**

**A1.2.1. Apparatus:**

A1.2.1.1. Any suitable high-speed (3000-r/min or higher) centrifuge of the continuous-flow type.³

A1.2.1.2. Balance—Conforming to the requirements of M 231, Class G 1.

A1.2.1.3. Funnel or Steam Hood.
A1.2.2. **Procedure:**

A1.2.2.1. Determine the mass of a clean, empty centrifuge cup (or bowl) to the nearest 0.01 g, and place it in the centrifuge. Position a container at the appropriate spout to catch the effluent from the centrifuging operation. Transfer all of the extract (from Method A, B, D, or E as appropriate) to an appropriate (feed) container suitably equipped with a feed control (valve or clamp, etc.). To ensure quantitative transfer of the extract to the feed container, the receptacle containing the extract should be washed several times with small amounts of clean solvent and the washings added to the feed container. Start the centrifuge, and allow it to reach a constant operational speed (e.g., 9000 r/min for the SMM type and 20,000 + r/min for the Sharples type). Open the feed line, and feed the extract into the centrifuge at a rate of 100 to 150 mL/min. After all the extract has passed through the centrifuge, wash the feed mechanism (with the centrifuge still running) with several increments of clean solvent, allowing each increment to run through the centrifuge until the effluent is essentially colorless.

A1.2.2.2. Allow the centrifuge to stop, and remove the cup (or bowl). Clean the outside with fresh solvent. Allow the residual solvent to evaporate in a funnel or steam hood, and then dry the container in an oven controlled at 110 ± 5°C (230 ± 9°F). Cool the container and redetermine the mass to the nearest 0.01 g immediately. The increase in mass is the mass of mineral matter, \( W_4 \) (Section 13), in the extract.

A1.3. **Volumetric Method:**

A1.3.1. **Apparatus:**

A1.3.1.1. Flask.

A1.3.1.2. Water Bath—Capable of controlling temperature to ±0.1°C (±0.2°F).

A1.3.1.3. Balance—Conforming to the requirements of M 231, Class G 2.

A1.3.2. **Procedure:**

A1.3.2.1. Place the extract in a previously tared and calibrated flask. Place the flask in a constant-temperature bath controlled to ±0.1°C (±0.2°F), and allow it to reach the temperature at which the flask was calibrated. When the desired temperature has been reached, fill the flask with solvent at the same temperature. Bring the level of the liquid in the flask up to the neck; insert the stopper, making sure the liquid overflows the capillary, and remove the flask from the bath. Wipe the flask dry; determine the mass to the nearest 0.1 g, and record the result as the mass of the contents of the flask, \( M_1 \).

**Note A1**—Instead of using a controlled temperature bath, the temperature of the extract may be measured and the necessary corrections to the volume of the flask and the density of the asphalt binder and solvent made.

A1.3.2.2. After the extracted aggregate has dried to a constant mass and cooled, determine the mass to the nearest 0.1 g. Record the mass of the initial sample minus the mass of the extracted aggregate as the mass of the asphalt binder and fines in the extract, \( M_2 \).

A1.3.2.3. Calculate the volume of asphalt and fines in the extract as follows:

\[
V_i = V_2 \left( \frac{M_1 - M_2}{G_i} \right) \quad (A1.2)
\]

where:

\[
V_1 = \text{volume of asphalt and fines in the extract, mL;}
\]
Volume of the flask, mL;
Mass of the contents of the flask, g;
Mass of the asphalt binder and fines in the extract (or mass of the initial sample minus the mass of the extracted aggregate), g; and Specific gravity of the solvent determined to the nearest 0.001 in accordance with ASTM D2111.

Calculate the mass of fines in the extract as follows:

\[ W_4 = K \left( M_2 - G_2 V_1 \right) \]

where:
Mass of mineral matter in the extract;
\[
K = \frac{G_2}{G_2 - G_3};
\]
Specific gravity of fines as determined in accordance with T 84;
Specific gravity of asphalt binder as determined in accordance with T 228;
Mass of the asphalt binder and fines in the extract (or mass of the initial sample minus the mass of the extracted aggregate); and
Volume of the flask.

1 This method is similar to ASTM D2172/D2172M-11.
2 Celite 110, manufactured by Johns-Manville, has been found satisfactory for this purpose; however, all filtering aids should be presieved through a 75-µm (No. 200) sieve when the gradation test on the aggregate is to be performed.
3 The Sharples Supercentrifuge and the SMM continuous-flow centrifuge have been found suitable for this method.
Standard Method of Test for

Bulk Specific Gravity \((G_{mb})\) of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens

AASHTO Designation: T 166-16

Technical Section: 2c, Asphalt–Aggregate Mixtures

Release: Group 3 (August)
1. **SCOPE**

1.1. This method of test covers the determination of bulk specific gravity ($G_{mb}$) of specimens of compacted asphalt mixtures.

1.2. This method should not be used with samples that contain open or interconnecting voids or absorb more than 2.0 percent of water by volume, as determined in Sections 7.2 or 10.2 herein. If the sample contains open or interconnecting voids or absorbs more than 2.0 percent of water by volume, then T 275 or T 331 should be used.

1.3. The bulk specific gravity ($G_{mb}$) of the compacted asphalt mixture may be used in calculating the unit mass of the mixture.

**Note 1**—The values for bulk specific gravity ($G_{mb}$) obtained from T 275 or T 331 may differ. Care should be exercised when comparing test results from T 275 and T 331.

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

1.5. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all 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
- R 79, Vacuum Drying Compacted Asphalt Specimens
- T 275, Bulk Specific Gravity ($G_{mb}$) of Compacted Asphalt Mixtures Using Paraffin-Coated Specimens
- T 331, Bulk Specific Gravity ($G_{mb}$) and Density of Compacted Asphalt Mixtures Using Automatic Vacuum Sealing Method

2.2. **ASTM Standards:**

- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
3. TERMINOLOGY

3.1. Definitions:

3.1.1. bulk specific gravity (of solids) \( (G_{mb}) \)—the ratio of the mass in air of a unit volume of a permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the mass in air of equal density of an equal volume of gas-free distilled water at a stated temperature. The form of the expression shall be:

\[
G_{mb} = \frac{m_x}{m_y} \quad (1)
\]

where:

\[x = \text{temperature of the material; and}\]

\[y = \text{temperature of the water.}\]

3.1.2. constant mass—shall be defined as the mass at which further drying does not alter the mass by more than 0.05 percent when weighed at 2-h intervals when using oven drying, or by more than 0.05 percent when weighed after at least two drying cycles of the vacuum-drying apparatus required in R 79.

4. TEST SPECIMENS

4.1. Test specimens may be either laboratory-compacted asphalt mixtures or sampled from asphalt pavements.

4.2. Size of Specimens—It is recommended that: (1) the diameter of cylindrically compacted or cored specimens, or the length of the sides of sawed specimens, be at least equal to four times the maximum size of the aggregate; and (2) the thickness of specimens be at least one and one-half times the maximum size of the aggregate.

4.3. Specimens shall be taken from pavements with a core drill, diamond or carborundum saw, or by other suitable means.

4.4. Care shall be taken to avoid distortion, bending, or cracking of specimens during and after the removal from the pavement or mold. Specimens shall be stored in a safe, cool place.

4.5. Specimens shall be free from foreign materials such as seal coat, tack coat, foundation material, soil, paper, or foil.

4.6. If desired, specimens may be separated from other pavement layers by sawing or other suitable means. Care should be exercised to ensure sawing does not damage the specimens.

METHOD A

5. APPARATUS

5.1. Weighing Device—The weighing device shall have sufficient capacity, be readable to 0.1 percent of the sample mass or better, and conform to the requirements of M 231. The weighing device shall be equipped with a suitable suspension apparatus and holder to permit weighing the specimen while suspended from the center of the scale pan of the weighing device.
5.2. **Suspension Apparatus**—The wire suspending the container shall be the smallest practical size to minimize any possible effects of a variable immersed length. The suspension apparatus shall be constructed to enable the container to be immersed to a depth sufficient to cover it and the test sample during weighing. Care should be exercised to ensure no trapped air bubbles exist under the specimen.

5.3. **Water Bath**—For immersing the specimen in water while suspended under the weighing device, equipped with an overflow outlet for maintaining a constant water level.

### 6. PROCEDURE

6.1. Dry the specimen to a constant mass at a temperature of 52 ± 3°C (125 ± 5°F). Samples saturated with water shall initially be dried overnight and then weighed at 2-h drying intervals. Recently compacted laboratory samples, which have not been exposed to moisture, do not require drying. As an alternative to oven drying to constant mass, drying the sample according to R 79 may be used. When using R 79 to achieve constant mass, perform the drying procedure at least twice, with a mass determination after each drying cycle.

6.2. Cool the specimen to room temperature at 25 ± 5°C (77 ± 9°F), and record the dry mass as $A$ (Note 2). Immerse each specimen in the water bath at 25 ± 1°C (77 ± 1.8°F) for 4 ± 1 min, and record the immersed mass as $C$. Remove the specimen from the water bath; damp-dry the specimen by blotting it with a damp towel, and determine the surface-dry mass as $B$ as quickly as possible (*the entire operation is not to exceed 15 s*). Any water that seeps from the specimen during the weighing operation is considered part of the saturated specimen. Each specimen shall be immersed and weighed individually.

**Note 2**—If desired, the sequence of testing operations may be changed to expedite the test results. For example, first the immersed mass $C$ can be taken, then the surface-dry mass $B$, and finally the dry mass $A$.

**Note 3**—Terry cloth has been found to work well for an absorbent cloth. Damp is considered to be when no water can be wrung from the towel.

### 7. CALCULATION

7.1. Calculate the bulk specific gravity ($G_{mb}$) of the specimen as follows:

$$\text{bulk specific gravity} = \frac{A}{B - C}$$

where:

- $A$ = mass of the specimen in air, g;
- $B$ = mass of the surface-dry specimen in air, g; and
- $C$ = mass of the specimen in water, g.

7.2. Calculate the percent of water absorbed by the specimen (on a volume basis) as follows:

$$\text{percent of water absorbed by volume} = \frac{B - A}{B - C} \times 100$$

7.3. If the percent of water absorbed by the specimen as calculated in Section 7.2 exceeds 2.0 percent, use either T 275 or T 331 to determine the bulk specific gravity ($G_{mb}$).
8. APPARATUS

8.1. **Weighing Device**—The weighing device shall have sufficient capacity, be readable to 0.1 percent of the sample mass or better, and conform to the requirements of M 231.

8.2. **Water Bath**—For immersing the specimen in water.

8.3. **Thermometer**—ASTM 17C (17°F) as provided in ASTM E1, having a range of 19 to 27°C (66 to 80°F), graduated in 0.1°C (0.2°F) subdivisions.

8.4. **Volumeter**—Calibrated to 1200 mL, or an appropriate capacity depending on the size of the test sample. The volumeter shall have a tapered lid with a capillary bore.

9. PROCEDURE

9.1. Dry the specimen to a constant mass at a temperature of 52 ± 3°C (125 ± 5°F). Samples saturated with water shall initially be dried overnight and then weighed at 2-h drying intervals. Recently compacted laboratory samples, which have not been exposed to moisture, do not require drying. As an alternative to oven drying to constant mass, drying using R 79 may be used. When using R 79 to achieve constant mass, perform the drying procedure at least twice, with a mass determination after each drying cycle.

9.2. Cool the specimen to room temperature at 25 ± 1°C (77 ± 1.8°F), and record the dry mass as \( A \) (Note 2). Immerse the specimen in the water bath at 25 ± 1°C (77 ± 1.8°F), and let it saturate for at least 10 min. At the end of the 10-min period, fill a calibrated volumeter with distilled water at 25 ± 1°C (77 ± 1.8°F), and weigh the volumeter. Designate this mass as \( D \). Remove the saturated specimen from the water bath and damp-dry the specimen by blotting with a damp towel (Note 3) as quickly as possible (not to exceed 5 s). Weigh the specimen, and record the surface-dry mass as \( B \). Any water that seeps from the specimen during the weighing operation is considered part of the saturated specimen.

9.3. Place the specimen into the volumeter, and let it stand for at least 60 s. Bring the temperature of the water to 25 ± 1°C (77 ± 1.8°F), and cover the volumeter, making certain that some water escapes through the capillary bore of the tapered lid. Wipe the outside of the volumeter dry with a dry, absorbent cloth, and weigh the volumeter and its contents (Note 4). Record this weight as \( E \). Note 4—If desired, the sequence of testing operations can be changed to expedite the test results. For example, first the mass of the saturated, damp-dry specimen \( B \) can be taken. Then the volumeter containing the saturated specimen and water \( E \) can be weighed. The dry mass of the specimen \( A \) can be determined last.

Note 5—Method B is not acceptable for specimens that have more than 6 percent air voids.

10. CALCULATIONS

10.1. Calculate the bulk specific gravity \( (G_{mb}) \) of the specimen as follows:

\[
\text{bulk specific gravity} = \frac{A}{B + D - E}
\]

where:

\( A \) = mass of the dry specimen, g;

\( B \) = mass of the saturated specimen, g;

\( D \) = mass of dry specimen, g;

\( E \) = mass of water displaced, g.
\[ B = \text{mass of the surface-dry specimen, g}; \]
\[ D = \text{mass of the volumeter filled with water at } 25 \pm 1^\circ C (77 \pm 1.8^\circ F), \text{g}; \text{ and} \]
\[ E = \text{mass of the volumeter filled with the specimen and water at } 25 \pm 1^\circ C (77 \pm 1.8^\circ F), \text{g}. \]

10.2. Calculate the percent of water absorbed by the specimen (on a volume basis) as follows:

\[
\text{percent of water absorbed by volume} = \left( \frac{B - A}{B + D - E} \right) \times 100 
\]

(5)

10.3. If the percent of water absorbed by the specimen as calculated in Section 10.2 exceeds 2.0 percent, use either T 275 or T 331 to determine the bulk specific gravity \( G_{mb} \).

---

**METHOD C (RAPID TEST)**

11. **PROCEDURE**

11.1. This procedure can be used for testing specimens that are not required to be saved and that contain a substantial amount of moisture. Specimens obtained by coring or sawing can be tested the same day by this method.

11.2. The testing procedure shall be the same as given in Section 6 or 9 except for the sequence of operations. The dry mass \( A \) of the specimen is determined last as follows:

11.2.1. Place the specimen in a large, flat-bottom drying pan of known mass. Place the pan and specimen in an oven at 110 ± 5°C (230 ± 9°F). Leave the specimen in the oven until it can be easily separated to the point where the particles of the fine aggregate-asphalt portion are not larger than 6.3 mm (\( \frac{1}{4} \) in.). Place the separated specimen in an oven at 110 ± 5°C (230 ± 9°F), and dry to a constant mass.

11.2.2. Cool the pan and specimen to room temperature at 25 ± 5°C (77 ± 9°F). Determine the mass of the pan and specimen, subtract the mass of the pan, and record as the dry mass, \( A \).

12. **CALCULATIONS**

12.1. Calculate the bulk specific gravity \( G_{mb} \) as given in Section 7.1 or 10.1.

13. **REPORT**

13.1. The report shall include the following:

13.1.1. The method used (A, B, or C).

13.1.2. Bulk specific gravity \( G_{mb} \) reported to the nearest thousandth.

13.1.3. Absorption reported to the nearest hundredth.
14. **PRECISION**

**Table 1**—Precision Estimates for T 166

<table>
<thead>
<tr>
<th>Condition of Test</th>
<th>Standard Deviation (1σ)*</th>
<th>Acceptable Range of Two Results (2σ)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-operator precision</td>
<td>0.002</td>
<td>0.006</td>
</tr>
<tr>
<td>Multilaboratory precision</td>
<td>0.006</td>
<td>0.017</td>
</tr>
</tbody>
</table>

* These values represent the 1σ and 2σ limits described in ASTM C670.

Note: Based on interlaboratory study described in NCHRP Research Report 9-26 Phase 2 involving 150-mm-diameter specimens, 20 laboratories, three materials (9.5-mm, 12.5-mm, and 19.0-mm mixtures), and two replicates.

15. **KEYWORDS**

15.1. Asphalt mixture; bulk specific gravity; saturated surface-dry; volumeter.

1 Suitable aluminum volumeters of different sizes are available from Pine Instrument Co., 101 Industrial Drive, Grove City, PA 16127; and Rainhart Co., 604 Williams St., Austin, TX 78765.
Standard Practice for Sampling Bituminous Paving Mixtures

This standard is issued under the fixed designation D979/D979M; 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 (´) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This practice covers sampling of bituminous paving mixtures at points of manufacture, storage, delivery, or in place.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with 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:

D2041 Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
D2234/D2234M Practice for Collection of a Gross Sample of Coal
D2726 Test Method for Bulk Specific Gravity and Density of Non-Absorbive Compacted Bituminous Mixtures
D3665 Practice for Random Sampling of Construction Materials
D5361 Practice for Sampling Compacted Bituminous Mixtures for Laboratory Testing
D5444 Test Method for Mechanical Size Analysis of Extracted Aggregate
D6307 Test Method for Asphalt Content of Hot-Mix Asphalt by Ignition Method
D6925 Test Method for Preparation and Determination of the Relative Density of Asphalt Mix Specimens by Means of the Superpave Gyratory Compactor
D6926 Practice for Preparation of Bituminous Specimens Using Marshall Apparatus
E105 Practice for Probability Sampling of Materials
E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process
E141 Practice for Acceptance of Evidence Based on the Results of Probability Sampling

2.2 AASHTO Standard:

R 47 Standard Practice for Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 field sample, n—a quantity of the material to be tested of sufficient size to provide an acceptable estimate of the average quality of a unit.

3.1.2 increment, n—part of a sample.

3.1.3 lot, n—a sizable isolated quantity of bulk material from a single source, assumed to have been produced by the same process (for example, a day’s production or a specific mass or volume).

3.1.4 test portion, n—a quantity of the material of sufficient size extracted from the larger field sample by a procedure designed to ensure accurate representation of the field sample, and thus of the unit sampled.

3.1.5 unit, n—a batch or finite subdivision of a lot of bulk material (for example, a truck load or a specific area covered).

4. Significance and Use

4.1 General:

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1 This practice is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and are the direct responsibility of Subcommittee D04.30 on Methods of Sampling.


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.

4.1.1 Sampling is equally as important as the testing, and the sampler shall take every precaution to obtain samples that will yield an acceptable estimate of the nature and conditions of the materials which they represent.

4.1.2 Samples for the development of preliminary data are obtained by the party responsible for the development of the data. Samples for control of the product at the source of manufacture or storage, or at the site of use, are obtained by the manufacturer, contractor, or other parties responsible for accomplishing the work. Samples for tests to be used in acceptance or rejection decisions by the purchaser are obtained by the purchaser or his authorized representative.

4.1.3 This standard shall not be used for the sampling of compacted bituminous paving mixtures. Practice D5361 shall be used.

5. Apparatus

5.1 Container—A bucket, pan, box, or other vessel of a sufficient size to contain the sample.

5.2 Release Agent—A non-stick product that promotes an easy separation of the bituminous paving mixture from the sampling tools without degrading the material being sampled.

5.3 Sampling Tool—A shovel, scoop, or other device used to obtain samples.

5.4 Truck Sampling Device (optional)—A mechanical apparatus that enables the user to retrieve material from the bed of a truck without standing in the bed of the truck. An example of one type of truck sampling device is shown in Fig. 1.

6. Procedure

6.1 Inspection—The material shall be inspected to determine discernible variations. The seller shall provide equipment needed for safe and appropriate inspection and sampling.

6.2 Release Agents—The user and producer of the bituminous paving mixtures must mutually agree upon the use of a release agent. If used, the approved release agent shall be lightly applied to the sampling tools and truck sampling device. Diesel fuel shall not be used.

6.3 Sampling—The procedures for selecting locations or times for sampling are described in Practice D3665.

6.3.1 Sampling from a Conveyor Belt—Stop the conveyor belt. Randomly select at least three areas of approximately equal size on the belt for sampling. In each of the locations to be sampled, insert templates, the shape of which conform to the shape of the belt. From the selected areas obtain approximately equal increments of material which will form a sample whose quantity equals or exceeds the minimum recommended in 6.4.2. Carefully scoop all material between templates into a suitable container.

6.3.2 Sampling from Truck Transports—By a random method, select the units to be sampled from the production of materials delivered. Obtain at least three approximately equal increments. Avoid sampling the extreme top surface. Select at random from the unit being sampled and combine to form a field sample whose quantity equals or exceeds the minimum recommended in 6.4.2. The sample may be obtained by collecting the increments with a truck sampling device, scoop, or shovel.

NOTE 1—Users should refer to the manufacturer’s instructions to learn how to properly operate and maintain a truck sampling device, if used.

6.3.3 Sampling from the Roadway Prior to Compaction—When only one sample is to be taken, obtain at least three approximately equal increments, selected at random from the unit being sampled, and combine to form a field sample whose quantity equals or exceeds the minimum recommended in 6.4.2.

6.3.3.1 When three or more samples are to be taken in order to evaluate a lot of material, utilize a random method to determine the locations to be sampled. Select a sample, consisting of approximately three equal increments, from each location, assuring the quantity of each sample exceeds the minimum recommended in 6.4.2.

6.3.3.2 Take all increments or samples from the roadway for the full depth of the material, taking care to exclude any underlying material. When necessary, place templates on the existing roadway to exclude any underlying material. Clearly mark the specified area from which each increment or sample is to be removed. Templates which are placed before the mixture is spread will be a definite aid securing increments of approximately equal mass.

6.3.4 Sampling from a Skip Conveyor Delivering Mixture to Bin Storage—Select the units to be sampled from the skip conveyor by a random method based on the bin’s storage capacity. Stop the skip conveyor immediately following pug mill discharge. Dig a furrow 150 mm [6 in.] in depth extending from the top to the bottom of the pile. Obtain three approximately equal increments from the top, middle, and bottom of the furrow depositing each increment in a container. The combined increments should form a field sample whose quantity equals or exceeds the minimum recommended in 6.4.2.

6.3.5 Sampling from a Funnel Device Feeding a Conveyor for Mixture Delivery to Storage—Select the units to be sampled from the skip conveyor by a random method based on the bin’s storage capacity. Stop the skip conveyor immediately following pug mill discharge. Dig a furrow 150 mm [6 in.] in depth extending from the top to the bottom of the pile. Obtain three approximately equal increments from the top, middle, and bottom of the furrow depositing each increment in a container. The combined increments should form a field sample whose quantity equals or exceeds the minimum recommended in 6.4.2.
from the funnel device by a random method based on the bin’s maximum storage capacity. Obtain at least three approximately equal increments of material for each sample by passing a bucket or pan or other suitable container across the full flow of materials as it drops from the funnel device onto the conveyor. The combined portions should form a field sample whose quantity equals or exceeds the minimum recommended in 6.4.2.

6.3.6 Sampling from Bituminous Cold Mix Stockpiles—Cold mixes that are in a stockpile for some time may develop a crust on the surface of the pile. This crust should be removed to a depth of 100 mm, over an area of one square meter, to expose the unweathered mix. Stir the exposed stockpile and obtain three approximately equal samples selected at random from the unit being sampled, and combine to form a field sample whose quantity equals or exceeds the minimum recommended in 6.4.2.

6.3.6.1 When three or more samples are to be taken, sample in accordance with 6.3.3.1.

6.4 Number and Quantities of Field Samples:

6.4.1 The number of field samples (obtained by one of the methods described in 6.3) required depends on the criticality of, and variation in, the properties to be measured. Designate each unit from which a field sample is to be obtained prior to sampling. The number of field samples from the production should be sufficient to give the desired confidence in test results.

NOTE 2—Guidance for determining the number of samples required to obtain the desired level of confidence in test results may be found in Practices D2234/D2234M, E105, E122, and E141.

NOTE 3—The unit to be represented by a single field sample should not be so large as to mask the effects of significant variability within the unit. Nor should a unit be so small as to be affected by the inherent variability between small portions of any bulk material.

NOTE 4—A unit of bulk material composed of graded aggregate or aggregate mixtures might consist of a full truckload. If it were possible, the entire load might be tested as a practical matter. A field sample is composed of three or more increments chosen at random from the material as it is loaded or unloaded from the truck. Research has shown that such a procedure permits an acceptable estimate to be made of the average gradation that might be measured from 15 or 20 increments from the truck.

NOTE 5—Significant variability within a lot of material, where it might exist, should be indicated by statistical measures, such as the standard deviation between units selected at random from within the lot.

6.4.2 The quantities of the material in the sample depend on the type and number of tests to which the material is to be subjected, and sufficient material must be obtained to provide for the proper execution of these tests. Standard control and acceptance tests are covered by ASTM standards and specify the portion of the field sample required for each specific test. Table 1 provides a guide of the minimum amounts of bituminous mixture that will be needed for routine testing for Test Methods D6307, D5444, D2041, D2726, D6925, and D6927, and Practice D6926. If there are to be additional tests, the sample size must be increased. If there are fewer tests to be performed, adjust the size of the sample accordingly. Extract test portions from the field sample by quartering or splitting in a similar manner to AASHTO Standard Practice R 47 or as required by other applicable test methods.

7. Shipping Samples

7.1 Transport samples in containers so constructed as to preclude loss or contamination of any part of the sample, or damage to the contents from mishandling during shipment.

7.2 Samples shall have individual identification attached giving the information required by the sample user. Typical information that may be useful could include, but not necessarily be limited to, the following:

7.2.1 Job for which the material is to be used, giving project number, highway route number, county, and other pertinent geographical information.

7.2.2 Source of sample, including for plant-mixed samples the name of owner or operator of plant, location of plant, type of plant, size of batch, and identification of bitumen and mineral aggregates used in the mixture.

7.2.3 Point at which sampled, for samples taken from roadway, both by station number and location transversely in pavement; also whether sampled from completed pavement, windrow, etc..

7.2.4 Quantity represented,
7.2.5 By whom sampled and title,
7.2.6 Date of most recent mixing, if road-mixed,
7.2.7 Date sampled,
7.2.8 By whom submitted and address,
7.2.9 Purpose for which sample was taken, and
7.2.10 To whom report is to be made.

8. Keywords

8.1 asphalt paving mixture; bituminous paving mixture; mechanical truck sampling device; sampling

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>25.0-mm (1-in.)</td>
<td>24 [52]</td>
<td>18 [5]</td>
</tr>
<tr>
<td>37.5-mm (11/2-in.)</td>
<td>30 [66]</td>
<td>22 [6]</td>
</tr>
<tr>
<td>50-mm (2-in.)</td>
<td>35 [75]</td>
<td>22 [6]</td>
</tr>
</tbody>
</table>

A The maximum size of aggregate is the largest sieve size listed in the applicable specification upon which any material is permitted to be retained.
Standard Method of Test for

Theoretical Maximum Specific Gravity ($G_{mm}$) and Density of Asphalt Mixtures

AASHTO Designation: T 209-19
Technical Subcommittee: 2c, Asphalt–Aggregate Mixtures
Release: Group 3 (July)
Standard Method of Test for

Theoretical Maximum Specific Gravity ($G_{mm}$) and Density of Asphalt Mixtures

AASHTO Designation: T 209-19

Technical Subcommittee: 2c, Asphalt–Aggregate Mixtures

Release: Group 3 (July)

1. SCOPE

1.1. This test method covers the determination of the theoretical maximum specific gravity/gravity mix maximum ($G_{mm}$) and density of uncompacted asphalt mixture at 25°C (77°F).

   Note 1—The precision of the method is best when the procedure is performed on samples that contain aggregates that are completely coated. In order to assure complete coating, it is desirable to perform the method on samples that are close to the optimum asphalt binder content.

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

1.3. This standard may involve hazardous materials, operations, and equipment. 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
   ■ R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
   ■ R 30, Mixture Conditioning of Hot Mix Asphalt (HMA)
   ■ R 47, Reducing Samples of Asphalt Mixtures to Testing Size
   ■ R 61, Establishing Requirements for Equipment Calibrations, Standardizations, and Checks
   ■ R 97, Sampling Asphalt Mixtures

2.2. ASTM Standard:

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

3. TERMINOLOGY

3.1. Definitions:
3.1.1. **Density**, as determined by this test method—the mass of a cubic meter of the material at 25°C (77°F) in SI units, or the mass of a cubic foot of the material at 25°C (77°F) in inch-pound units.

3.1.2. **Residual Pressure**, as employed by this test method—the pressure in a vacuum vessel when vacuum is applied.

3.1.3. **Specific Gravity**, as determined by this test method—the ratio of a given mass of material at 25°C (77°F) to the mass of an equal volume of water at the same temperature.

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4. **SIGNIFICANCE AND USE**

4.1. The theoretical maximum specific gravity ($G_{mm}$) and density of asphalt mixture are intrinsic properties whose values are influenced by the composition of the mixtures in terms of types and amounts of aggregates and asphalt materials.

4.1.1. These properties are used to calculate percent air voids in compacted asphalt mixture.

4.1.2. These properties provide target values for the compaction of asphalt mixture.

4.1.3. These properties are essential when calculating the amount of asphalt binder absorbed by the internal porosity of the individual aggregate particles in asphalt mixture.

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5. **APPARATUS**

5.1. Follow the procedures for performing equipment calibrations, standardizations, and checks that conform to R 18 and R 61.

5.2. **Vacuum Container**:

5.2.1. The vacuum containers described must be capable of withstanding the full vacuum applied, and each must be equipped with the fittings and other accessories required by the test procedure being employed. The opening in the container leading to the vacuum pump shall be covered by a piece of 0.075-mm (No. 200) wire mesh to minimize the loss of fine material.

5.2.2. The capacity of the vacuum container should be between 2000 and 10 000 mL and depends on the minimum sample size requirements given in Section 6.3. Avoid using a small sample in a large container.

5.2.3. **Bowl for Mass Determination in Water Only (Section 11.1)**—Either a metal or plastic bowl with a diameter of approximately 180 to 260 mm (7 to 10 in.) and a bowl height of at least 160 mm (6.3 in.) equipped with a transparent cover fitted with a rubber gasket and a connection for the vacuum line.

5.2.4. **Flask for Mass Determination in Air Only (Section 11.2)**—A thick-walled volumetric glass flask with a factory-inscribed line and a rubber stopper with a connection for the vacuum line.

5.2.5. **Pycnometer for Mass Determination in Air Only (Section 11.2)**—A glass, metal, or plastic pycnometer with a volume defined by means of a glass capillary stopper, capillary lid, or glass plate.

5.3. **Balance**—A balance conforming to the requirements of M 231, Class G 2. The balance shall be standardized at least every 12 months.
5.3.1. For the mass determination-in-water method (Section 11.1), the balance shall be equipped with a suitable apparatus and holder to permit determining the mass of the sample while suspended below the balance. The wire suspending the holder shall be the smallest practical size to minimize any possible effects of a variable immersed length.

5.4. *Vacuum Pump or Water Aspirator*—Capable of evacuating air from the vacuum container to a residual pressure of 4.0 kPa (30 mmHg).

5.4.1. When an oil vacuum pump is used, a suitable trap of one or more filter flasks, or equivalent, shall be installed between the vacuum vessel and vacuum source to reduce the amount of water vapor entering the vacuum pump.

5.5. *Vacuum Measurement Device*—Residual pressure manometer\(^1\) or vacuum gauge to be connected directly to the vacuum vessel and capable of measuring residual pressure down to 4.0 kPa (30 mmHg) or less (preferably to zero). The device shall be standardized at least annually and be accurate to 0.1 kPa (1 mmHg). It shall be connected at the end of the vacuum line using an appropriate tube and either a “T” connector on the top of the vessel or a separate opening (from the vacuum line) in the top of the vessel to attach the hose. To avoid damage, the manometer shall not be situated on top of the vessel.

**Note 2**—A residual pressure of 4.0 kPa (30 mmHg) absolute pressure is approximately equivalent to a 97 kPa (730 mmHg) reading on a vacuum gauge at sea level.

**Note 3**—Residual pressure in the vacuum container, measured in millimeters of mercury, is the difference in the height of mercury in the Torricellian vacuum leg of the manometer and the height of mercury in the other leg of the manometer that is attached to the vacuum container.

**Note 4**—An example of a suitable arrangement of the testing equipment is shown in Figure 1. In the figure, the purpose of the train of small filter flasks is to trap water vapor from the vacuum container that otherwise would enter the oil in the vacuum pump and decrease the pump’s ability to provide adequate vacuum.

![Figure 1—Example of Suitable Arrangement of Testing Apparatus](image)

5.6. *Bleeder Valve*—attached to the vacuum train to facilitate adjustment of the vacuum being applied to the vacuum container.
5.7. **Thermometer (Mass Determination in Air)**—A liquid-in-glass thermometer or other thermometric device, accurate to 0.5°C (1°F), of suitable range with subdivisions of 0.5°C (1°F). The thermometer shall be standardized at the test temperature at least every 12 months.

5.8. **Drying Oven**—A thermostatically controlled drying oven capable of maintaining a temperature of 135 ± 5°C (275 ± 9°F) or 105 ± 5°C (221 ± 9°F).

5.8.1. **Thermometer**—A liquid-in-glass thermometer or other thermometric device accurate to 3°C (5°F) shall be used to measure the temperature of the oven. The thermometer shall be standardized at least every 12 months.

5.9. **Water Bath**:

5.9.1. For bowls, a water bath capable of maintaining a constant temperature between 20 and 30°C (68 and 86°F) is required.

5.9.2. **Thermometer (Mass Determination in Water)**—A liquid-in-glass thermometer or other thermometric device, accurate to 0.5°C (1°F) shall be used to measure the temperature of the water bath. The thermometer shall be standardized at least every 12 months.

5.9.3. When using the mass determination-in-water technique (Section 13.1), the water bath must be suitable for immersion of the suspended container with its deaerated sample.

5.10. **Protective Gloves**—Used when handling glass equipment under vacuum.

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### 6. SAMPLING

6.1. **Plant-Produced**

6.1.1. Obtain the sample in accordance with R 97.

6.1.2. Reduce the sample in accordance with R 47.

6.2. **Laboratory-Prepared**

6.2.1. When necessary, reduce samples prepared or produced in a laboratory in accordance with R 47.

6.3. The size of the sample shall conform to the following requirements. Samples larger than the capacity of the container may be tested a portion at a time.

<table>
<thead>
<tr>
<th>Nominal Maximum Aggregate Size, mm</th>
<th>Minimum Sample Size, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5 or greater</td>
<td>4000</td>
</tr>
<tr>
<td>19 to 25</td>
<td>2500</td>
</tr>
<tr>
<td>12.5 or smaller</td>
<td>1500</td>
</tr>
</tbody>
</table>

### 7. SAMPLE PREPARATION

7.1. **Laboratory-Prepared Samples**
Samples prepared in a laboratory shall be short-term conditioned according to R 30. This conditioning shall be combined with any warming described in Section 7.3.

Plant-Produced Samples

Dry the sample to a constant mass at a temperature of 105 ± 5°C (221 ± 9°F) until further drying does not alter the mass by more than 0.1 percent. Drying shall be combined with any warming described in Section 7.3.

Note 5—Short-term conditioning at the specified temperature is especially important when absorptive aggregates are used. This short-term conditioning will ensure the computation of realistic values for the amount of asphalt absorbed by the aggregate and void properties of the mix. Plant-produced asphalt mixtures should be evaluated to make sure short-term conditioning has taken place during production and delivery.

Separate the particles of the asphalt mixture sample by hand, taking care to avoid fracturing the aggregate, so that the particles of the fine aggregate portion are not larger than 6.3 mm (1/4 in.). If an asphalt mixture sample is not sufficiently soft to be separated manually, place it in a pan and warm it in an oven until it can be separated as described.

Determine and record the mass of the empty vacuum container.

Cool the sample to room temperature, and place the sample in the vacuum container. A container within a container is not to be used. Determine and record the mass of the sample and container. Subtract the mass of the container from the mass of the sample and the container. Record the net mass of the sample as \( A \).

Add sufficient water at a temperature of approximately 25°C (77°F) to cover the sample completely.

Note 6—The release of entrapped air may be facilitated by the addition of a suitable wetting agent such as Aerosol OT in concentration of 0.001 percent or 0.2 g in 20 L of water. This solution is then diluted by about 20:1 to make a wetting agent of which 5 to 10 mL may be added to the apparatus.

TEST METHOD A—MEchanical AgITATION

APPARATUS

In addition to the apparatus listed in Section 5, the following apparatus is required for Method A:

Mechanical Shaker—Shaker for removing air from asphalt mixture.

PROCEDURE

Remove air trapped in the sample by applying gradually increased vacuum until the residual pressure manometer reads 3.7 ± 0.3 kPa (27.5 ± 2.5 mmHg). Maintain this residual pressure for 15 ± 2 min. Agitate the container and contents using the mechanical device during the vacuum period. Glass vessels should be shaken on a resilient surface such as a rubber or plastic mat, and not on a hard surface, so as to avoid excessive impact while under vacuum.

At the end of the vacuum period, release the vacuum by increasing the pressure at a rate not to exceed 8 kPa (60 mmHg) per second and proceed with one of the mass determination methods in Section 11.
10. PROCEDURE

10.1. Remove air trapped in the sample by applying gradually increased vacuum until the residual pressure manometer reads 3.7 ± 0.3 kPa (27.5 ± 2.5 mmHg). Maintain this residual pressure for 15 ± 2 min. Agitate the container and contents during the vacuum period by vigorously shaking at intervals of about 2 min. Glass vessels should be shaken on a resilient surface such as a rubber or plastic mat, and not on a hard surface, so as to avoid excessive impact while under vacuum.

10.2. At the end of the vacuum period, release the vacuum by increasing the pressure at a rate not to exceed 8 kPa (60 mmHg) per second and proceed with one of the mass determination methods in Section 11.

11. MASS DETERMINATION

11.1. Mass Determination in Water—Suspend the container and contents in a water bath at 25 ± 1°C (77 ± 2°F). Determine and record the mass after a 10 ± 1 min immersion. Designate the mass of the sample and container in water as C.

11.2. Mass Determination in Air—Fill the flask or any one of the pycnometers with water and adjust the contents to a temperature of 25 ± 1°C (77 ± 2°F). Determine and record the mass of the container and contents, completely filled, in accordance with Section A1.2.1 within 10 ± 1 min after the vacuum has been released. Designate this mass as E.

12. CALCULATION

12.1. Theoretical maximum specific gravity ($G_{mm}$)

12.1.1. Calculate the theoretical maximum specific gravity ($G_{mm}$) of the sample at 25°C (77°F) as follows:

12.1.2. Mass Determination in Water:

$$G_{mm} = \frac{A}{A + B - C} \quad (1)$$

where:

- $A$ = mass of the oven-dry sample in air, g;
- $B$ = mass of the container submerged in water, g, determined in accordance with Section A1.1; and
- $C$ = mass of the sample and container in water, g.

12.1.3. Mass Determination in Air:

$$G_{mm} = \frac{A}{A + D - E} \quad (2)$$

where:

- $A$ = mass of the oven-dry sample in air, g;
- $D$ = mass of the container filled with water, g; determined in accordance with Section A1.2; and
- $E$ = mass of the container filled with the sample and water, g.
12.2. *Theoretical maximum density* \( (G_{\text{mm}}) \) at 25°C (77°F):

12.2.1. Calculate the corresponding theoretical maximum density \( (G_{\text{mm}}) \) at 25°C (77°F) as follows:

Theoretical maximum density at 25°C (77°F) = theoretical maximum specific gravity \( \times \) 997.1 kg/m\(^3\) in SI units.

or

Theoretical maximum density at 25°C (77°F) = theoretical maximum specific gravity \( \times \) 62.245 lb/ft\(^3\) in inch-pound units.

where:

The density of water at 25°C (77°F) = 997.1 kg/m\(^3\) in SI units or 62.245 lb/ft\(^3\) in inch-pound units.

13. **SUPPLEMENTAL PROCEDURE FOR MIXTURES CONTAINING POROUS AGGREGATE**

*Note 7—Experiments indicate that this supplemental procedure has an insignificant effect on the test results if the asphalt mixture contains individual aggregate with a water absorption below 1.5 percent.*

13.1. If the pores of the aggregates are not thoroughly sealed by an asphalt film, they may become saturated with water during the application of vacuum. To determine if this condition has occurred, proceed as follows after completing Section 11.1 or 11.2. Drain the water from the sample. To prevent the loss of fine particles, decant the water through a towel held over the top of the container. Break several large pieces of aggregate and examine the broken surfaces for wetness.

13.2. If the aggregate has absorbed water, spread the sample before an electric fan to remove the surface moisture. Determine and record the mass at 15-min intervals, and when the loss in mass is less than 0.05 percent for this interval, the sample may be considered to be “surface dry.” This procedure requires about 2 h and shall be accompanied by intermittent stirring of the sample. Break conglomerations of the asphalt mixture by hand. Take care to prevent the loss of asphalt mixture particles.

13.3. To calculate the specific gravity of the sample, substitute the final surface-dry mass determined in Section 13.2 for \( A \) in the denominator of Equation 2 or 3 as appropriate.

14. **REPORT**

14.1. *Report the following information:*

14.1.1. \( G_{\text{mm}} \) and density of the asphalt mixture to the nearest 0.001 for specific gravity or nearest 1 kg/m\(^3\) (0.1 lb/ft\(^3\)) for density as follows: sp gr 25/25°C (77/77°F) or density at 25°C (77°F);

14.1.2. Type of asphalt mixture;

14.1.3. Size of the sample;

14.1.4. Number of samples;

14.1.5. Type of container; and

14.1.6. Type of procedure.
15. **PRECISION**

15.1. Criteria for judging the acceptability of specific gravity test results obtained by this test method are given in the following table:

<table>
<thead>
<tr>
<th>Test and Type Index</th>
<th>Standard Deviation (1σ)</th>
<th>Acceptable Range of Two Results (d2σ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test results obtained without use of Section 15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Method A&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-operator precision</td>
<td>0.0051</td>
<td>0.014</td>
</tr>
<tr>
<td>Multilaboratory precision</td>
<td>0.0084</td>
<td>0.024</td>
</tr>
<tr>
<td>Method B&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-operator precision</td>
<td>0.0064</td>
<td>0.018</td>
</tr>
<tr>
<td>Multilaboratory precision</td>
<td>0.0103</td>
<td>0.029</td>
</tr>
</tbody>
</table>

<sup>a</sup> Basis of estimate: 1 replicate, 1 material, 344 laboratories.

<sup>b</sup> Basis of estimate: 1 replicate, 1 material, 134 laboratories.

15.2. The figures given in Column 2 are the standard deviations that have been found to be appropriate for the conditions of the test described in Column 1. The figures given in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests. Multilaboratory precision has not been verified for 4500-mL or larger pycnometers.

15.3. The values in Column 3 are the acceptable range for two tests. When more than two results are being evaluated, the range given in Column 3 must be increased. Multiply the standard deviation(s) in Column 2 by the multiplier given in Table 1 of ASTM C670 for the number of actual tests.

Example for three tests: $0.004 \times 3.3 = 0.013$.

Additional guidance and background is given in ASTM C670.

16. **KEYWORDS**

16.1. Agitation; asphalt mixture; maximum density; maximum specific gravity; pycnometer; vacuum.

**ANNEX**

(Mandatory Information)

**A1. STANDARDIZATION OF BOWLS, FLASKS, AND PYCNOMETERS**

A1.1. *Standardization and Check of Bowl for Mass Determination in Water*

A1.1.1 *Standardization*—Immerse an empty bowl in water at 25 ± 1°C (77 ± 2°F) for 10 ± 1 min. Determine and record the mass of bowl. Repeat this process three times. If the three masses are within 0.3 g, use the average as B in Equation 2. If the variation of the masses is greater than 0.3 g take corrective action and perform standardization procedure again.
A1.2.1  Check—Perform the mass determination of the bowl as described in A1.2.1. If this determination is within 0.3 g of the standardized value, use the standardized value for C. If it is not within 0.3 g, perform the standardization procedure again.

A1.2  Standardization and Check of Flask and Pycnometer for Mass Determination in Air

A1.2.1  Standardization—Fill the flask or pycnometer with water at approximately 25 °C (77°F). Use a glass capillary stopper, capillary lid, or glass plate to ensure all entrapped air is removed. Stabilize the flask or pycnometer at 25 ± 1°C (77 ± 2°F) for 10 ± 1 min. Determine and record the mass of the flask or pycnometer, water, and lid. Repeat this process three times. If the three masses are within 0.3 g, use the average of the three masses as D in Equation 3. If the variation of the masses is greater than 0.3 g, take corrective action and perform the standardization procedure again.

1 Sargent Welch, 39745 Gauge-Vacuum, Mercury Prefilled (or equivalent).
Standard Method of Test for

Resistance to Plastic Flow
of Asphalt Mixtures Using
Marshall Apparatus


Technical Subcommittee: 2d, Proportioning
of Asphalt–Aggregate Mixtures

Release: Group 3 (July)
Standard Method of Test for


Technical Subcommittee: 2d, Proportioning of Asphalt–Aggregate Mixtures

Release: Group 3 (July)

1. SCOPE

1.1. This method covers the measurement of the resistance to plastic flow of cylindrical specimens of asphalt mixture loaded on the lateral surface by means of the Marshall apparatus. This method is for use with mixtures containing asphalt binder or asphalt cutback and aggregate up to 25.4-mm (1-in.) maximum size.

2. REFERENCED DOCUMENTS

2.1. AASHTO Standard:
   - R 68, Preparation of Asphalt Mixture Specimens by Means of the Marshall Compactor

2.2. ASTM Standards:
   - C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
   - D3549/D3549M, Standard Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens

3. APPARATUS

3.1. Breaking Head (Figure 1)—Shall consist of upper and lower cylindrical segments or test heads having an inside radius of curvature of 50.8 mm (2 in.) accurately machined. The lower segment shall be mounted on a base having two perpendicular guide rods or posts extending upward. Guide sleeves in the upper segment shall be in such a position as to direct the two segments together without appreciable binding or loose motion on the guide rods.
Figure 1—Breaking Head

(See Table 1 for Equivalents)
Table 1—Table of Equivalents for Figure 1

<table>
<thead>
<tr>
<th>Metric Equivalents, mm</th>
<th>U.S. Customary Units, in.</th>
<th>Metric Equivalents, mm</th>
<th>U.S. Customary Units, in.</th>
<th>Metric Equivalents, mm</th>
<th>U.S. Customary Units, in.</th>
<th>Metric Equivalents, mm</th>
<th>U.S. Customary Units, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.11</td>
<td>0.005</td>
<td>17.5</td>
<td>1/16 2/32</td>
<td>58.7</td>
<td>2 3/16</td>
<td>104.8</td>
<td>4 1/8</td>
</tr>
<tr>
<td>0.8</td>
<td>1/32</td>
<td>19.0</td>
<td>3/32 7/32</td>
<td>63.5</td>
<td>2 3/4</td>
<td>108.7</td>
<td>4 7/32</td>
</tr>
<tr>
<td>1.6</td>
<td>1/16</td>
<td>22.2</td>
<td>7/32 2 3/16</td>
<td>69.8</td>
<td>2 3/4</td>
<td>109.1</td>
<td>4 5/16</td>
</tr>
<tr>
<td>3.2</td>
<td>1/8</td>
<td>23.8</td>
<td>15/16 5 7/16</td>
<td>73.0</td>
<td>2 3/16</td>
<td>114.3</td>
<td>4 3/2</td>
</tr>
<tr>
<td>4.8</td>
<td>3/16</td>
<td>25.4</td>
<td>1 7/16 10 3/16</td>
<td>76.2</td>
<td>3</td>
<td>117.5</td>
<td>4 3/16</td>
</tr>
<tr>
<td>6.4</td>
<td>1/4</td>
<td>28.6</td>
<td>1 1/8 13 1/4</td>
<td>82.6</td>
<td>3 3/16</td>
<td>120.6</td>
<td>4 5/16</td>
</tr>
<tr>
<td>7.1</td>
<td>5/32</td>
<td>31.8</td>
<td>1 1/4 15 1/8</td>
<td>87.3</td>
<td>3 3/16</td>
<td>128.6</td>
<td>5 3/16</td>
</tr>
<tr>
<td>9.5</td>
<td>3/4</td>
<td>34.9</td>
<td>1 1/2 18 1/2</td>
<td>98.4</td>
<td>3/4</td>
<td>130.2</td>
<td>5 1/8</td>
</tr>
<tr>
<td>12.6</td>
<td>0.496</td>
<td>38.1</td>
<td>1 1/2 21 3/4</td>
<td>101.2</td>
<td>3/4</td>
<td>146.0</td>
<td>5 1/2</td>
</tr>
<tr>
<td>12.67</td>
<td>0.499</td>
<td>41.3</td>
<td>1 5/8 22 1/2</td>
<td>101.35</td>
<td>3.990</td>
<td>152.4</td>
<td>6</td>
</tr>
<tr>
<td>12.7</td>
<td>1/2</td>
<td>44.4</td>
<td>1 3/4 23 1/4</td>
<td>101.47</td>
<td>3.995</td>
<td>158.8</td>
<td>6 1/4</td>
</tr>
<tr>
<td>14.3</td>
<td>5/16</td>
<td>50.8</td>
<td>2 24 1/2</td>
<td>101.6</td>
<td>4</td>
<td>193.7</td>
<td>7 1/8</td>
</tr>
<tr>
<td>15.9</td>
<td>5/16</td>
<td>57.2</td>
<td>2 3/4 24 5/4</td>
<td>101.73</td>
<td>4.005</td>
<td>685.8</td>
<td>27</td>
</tr>
</tbody>
</table>

3.2. **Loading Jack**—The loading jack (Figure 2) shall consist of a screw jack mounted in a testing frame and shall produce a uniform vertical movement of 50.8 mm (2 in.)/min. An electric motor may be attached to the jacking mechanism.

![Figure 2—Loading Jack](image.png)

**Note 1**—Instead of the loading jack, a mechanical or hydraulic testing machine may be used, provided the rate of movement can be maintained at 50.8 mm (2 in.)/min while the load is applied.
3.3. **Ring Dynamometer Assembly**—One-ring dynamometer (Figure 2) of 22.2-kN (5000-lb) capacity and sensitivity of 44.5 N (10 lb) up to 4.45 kN (1000 lb) and 111.2 N (25 lb) between 4.45 and 22.2 kN (1000 and 5000 lb) shall be equipped with a micrometer dial. The micrometer dial shall be graduated in 0.0025 mm (0.0001 in.) increments. Upper and lower ring dynamometer attachments are required for fastening the ring dynamometer to the testing frame and transmitting the load to the breaking head. Instead of the ring dynamometer assembly, any suitable load-measuring device may be used, provided the capacity and sensitivity satisfy the above requirements.

3.4. **Flowmeter**—The flowmeter shall consist of a guide sleeve and a gauge. The activating pin of the gauge shall slide inside the guide sleeve with a slight amount of frictional resistance. The guide sleeve shall slide freely over the guide rod of the breaking head. The flowmeter gauge shall be adjusted to zero when placed in position on the breaking head when each individual test specimen is inserted between the breaking head segments. Graduations of the flowmeter gauge shall be in 0.25-mm (0.01-in.) divisions. Instead of the flowmeter, a micrometer dial or stress–strain recorder graduated in 0.25 mm (0.01 in.) increments may be used to measure flow.

3.5. **Ovens or Hot Plates**—Ovens or hot plates shall be provided for heating aggregates, asphalt material, specimen molds, compaction hammers, and other equipment to the required mixing and molding temperatures. It is recommended that the heating units be thermostatically controlled so as to maintain the required temperature within 2.8°C (5°F). Suitable shields, baffle plates, or sand baths shall be used on the surfaces of the hot plates to minimize localized overheating.

3.6. **Water Bath**—The water bath shall be at least 152.4 mm (6 in.) deep and shall be thermostatically controlled so as to maintain the bath at 60 ± 1°C (140 ± 1.8°F) or 37.8 ± 1°C (100 ± 2°F). The tank shall have a perforated false bottom or be equipped with a shelf for supporting specimens 50.8 mm (2 in.) above the bottom of the bath.

3.7. **Air Bath**—The air bath for asphalt cutback mixtures shall be thermostatically controlled and shall maintain the air temperature at 25 ± 1°C (77° ± 2°F).

3.8. **Thermometers**—For water and air baths sensitive to 0.2°C (0.4°F) with a range sufficient to determine the specified bath temperature.

3.9. **Vernier Calipers**—Calipers readable to 0.1 mm (0.004 in.)

3.10. **Gloves**—For handling hot equipment and other gloves for removing specimens from water bath.

**4. TEST SPECIMENS**

4.1. **Number and Dimension of Specimens**—Three cylindrical specimens, 101.6 ± 0.1 mm (4.0 ± 0.05 in.) in diameter and ranging from 25.4 mm (1.0 in.) to 76.2 mm (3.0 in.) tall, are recommended. Prepare specimens in accordance with AASHTO R 68.

4.2. **Roadway Core Specimens**—Core specimens meeting the dimensional requirements of Section 4.1 may be collected in accordance with D5361/D5361M.

**5. PROCEDURE**

5.1. Measure specimen height in accordance with ASTM D3549/D3549M.

5.2. Bring the specimens prepared with asphalt cement to the specified temperature by immersing in the water bath 30 to 40 min or placing in the oven for 2 h. Maintain the bath or oven temperature at 60 ± 1°C (140 ± 1.8°F) for the asphalt binder specimens. Bring the specimens prepared with
asphalt cutback to the specified temperature by placing them in the air bath for a minimum of 2 h. Maintain the air bath temperature at 25 ± 1°C (77 ± 1.8°F). Thoroughly clean the guide rods and the inside surfaces of the test heads prior to performing the test, and lubricate the guide rods so that the upper test head slides freely over them. The testing-head temperature shall be maintained between 21.1 to 37.8°C (70 to 100°F) using a water bath when required. Remove the specimen from the water bath, oven, or air bath, and place in the lower segment of the breaking head. Place the upper segment of the breaking head on the specimen, and place the complete assembly in position on the testing machine. Place the flowmeter, where used, in position over one of the guide rods and adjust the flowmeter to zero while holding the sleeve firmly against the upper segment of the breaking head. Hold the flowmeter sleeve firmly against the upper segment of the breaking head while the test load is being applied.

5.3. Apply the load to the specimen by means of the constant rate of movement of the loading jack or testing-machine head of 50.8 mm (2 in.) per minute until the maximum load is reached and the load decreases as indicated by the dial. Record the maximum load noted on the testing machine or converted from the maximum micrometer dial reading. Release the flowmeter sleeve or note the micrometer dial reading, where used, the instant the maximum load begins to decrease. Note and record the indicated flow value or equivalent units in twenty-five hundredths of a millimeter (hundredths of an inch) if a micrometer dial is used to measure the flow. The elapsed time for the test from removal of the test specimen from the water bath to the maximum load determination shall not exceed 30 s.

Note 2—For core specimens, correct the load when thickness is other than 63.5 mm (2½ in.) by using the proper multiplying factor from Table 2.
### Table 2—Stability Correlation Ratios\(^a,b\)

<table>
<thead>
<tr>
<th>Volume of Specimen, (cm^3)</th>
<th>Approximate Thickness of Specimen, (in.)</th>
<th>Correlation Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 to 213</td>
<td>1</td>
<td>5.56</td>
</tr>
<tr>
<td>214 to 225</td>
<td>1(\frac{1}{16})</td>
<td>5.00</td>
</tr>
<tr>
<td>226 to 237</td>
<td>1(\frac{1}{8})</td>
<td>4.55</td>
</tr>
<tr>
<td>238 to 250</td>
<td>1(\frac{1}{16})</td>
<td>4.17</td>
</tr>
<tr>
<td>251 to 264</td>
<td>1(\frac{1}{16})</td>
<td>3.85</td>
</tr>
<tr>
<td>265 to 276</td>
<td>1(\frac{1}{8})</td>
<td>3.57</td>
</tr>
<tr>
<td>277 to 289</td>
<td>1(\frac{3}{16})</td>
<td>3.33</td>
</tr>
<tr>
<td>290 to 301</td>
<td>1(\frac{1}{16})</td>
<td>3.03</td>
</tr>
<tr>
<td>302 to 316</td>
<td>1(\frac{1}{2})</td>
<td>2.78</td>
</tr>
<tr>
<td>317 to 328</td>
<td>1(\frac{1}{16})</td>
<td>2.50</td>
</tr>
<tr>
<td>329 to 340</td>
<td>1(\frac{3}{16})</td>
<td>2.27</td>
</tr>
<tr>
<td>341 to 353</td>
<td>1(\frac{1}{16})</td>
<td>2.08</td>
</tr>
<tr>
<td>354 to 367</td>
<td>1(\frac{1}{8})</td>
<td>1.92</td>
</tr>
<tr>
<td>368 to 379</td>
<td>1(\frac{3}{16})</td>
<td>1.79</td>
</tr>
<tr>
<td>380 to 392</td>
<td>1(\frac{5}{16})</td>
<td>1.67</td>
</tr>
<tr>
<td>393 to 405</td>
<td>1(\frac{3}{8})</td>
<td>1.56</td>
</tr>
<tr>
<td>406 to 420</td>
<td>2</td>
<td>1.47</td>
</tr>
<tr>
<td>421 to 431</td>
<td>2(\frac{1}{16})</td>
<td>1.39</td>
</tr>
<tr>
<td>432 to 443</td>
<td>2(\frac{1}{8})</td>
<td>1.32</td>
</tr>
<tr>
<td>444 to 456</td>
<td>2(\frac{1}{16})</td>
<td>1.25</td>
</tr>
<tr>
<td>457 to 470</td>
<td>2(\frac{1}{8})</td>
<td>1.19</td>
</tr>
<tr>
<td>471 to 482</td>
<td>2(\frac{1}{16})</td>
<td>1.14</td>
</tr>
<tr>
<td>483 to 495</td>
<td>2(\frac{1}{16})</td>
<td>1.09</td>
</tr>
<tr>
<td>496 to 508</td>
<td>2(\frac{1}{16})</td>
<td>1.04</td>
</tr>
<tr>
<td>509 to 522</td>
<td>2(\frac{1}{2})</td>
<td>1.00</td>
</tr>
<tr>
<td>523 to 535</td>
<td>2(\frac{1}{16})</td>
<td>0.96</td>
</tr>
<tr>
<td>536 to 546</td>
<td>2(\frac{1}{4})</td>
<td>0.93</td>
</tr>
<tr>
<td>547 to 559</td>
<td>2(\frac{1}{16})</td>
<td>0.89</td>
</tr>
<tr>
<td>560 to 573</td>
<td>2(\frac{1}{4})</td>
<td>0.86</td>
</tr>
<tr>
<td>574 to 585</td>
<td>2(\frac{1}{16})</td>
<td>0.83</td>
</tr>
<tr>
<td>586 to 598</td>
<td>2(\frac{1}{3})</td>
<td>0.81</td>
</tr>
<tr>
<td>599 to 610</td>
<td>2(\frac{3}{16})</td>
<td>0.78</td>
</tr>
<tr>
<td>611 to 625</td>
<td>3</td>
<td>0.76</td>
</tr>
</tbody>
</table>

\(^a\) The measured stability of a specimen multiplied by the ratio for the thickness of the specimen equals the corrected stability for a 63.5-mm (2\(\frac{1}{8}\)-in.) specimen.

\(^b\) Volume–thickness relationship is based on a specimen diameter of 101.6 mm (4 in.).

### 6. REPORT

6.1. The report shall include the following information:

6.1.1. Type of sample tested (laboratory sample or pavement core specimen);

**Note 3**—For core specimens, the height of each test specimen in millimeters (or inches) shall be reported.

6.1.2. Average maximum load in pounds-force (or newtons) of at least three specimens, corrected when required;
6.1.3. Average flow value, in twenty-five hundredths of a millimeter (hundredths of an inch), of three specimens; and

6.1.4. Test temperature.

7. PRECISION AND BIAS

7.1. Criteria for judging the acceptability of Marshall stability and flow test results obtained by this method are shown in Table 3.

Table 3—Precision Estimates

<table>
<thead>
<tr>
<th>Test and Type of Index</th>
<th>Coefficient of Variation, % of mean&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Acceptable Range of Two Test Results, % of mean&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marshall stability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within laboratory precision</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>Between laboratory precision</td>
<td>16</td>
<td>43</td>
</tr>
<tr>
<td>Marshall flow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within laboratory precision</td>
<td>9</td>
<td>26</td>
</tr>
<tr>
<td>Between laboratory precision</td>
<td>20</td>
<td>58</td>
</tr>
</tbody>
</table>

<sup>a</sup> These values represent the 1s percent and 2s percent limits as described in ASTM C670.

7.2. The precision estimates noted in Table 3 are based on specimens compacted with mechanical and manual hammers and include dense graded mixtures with limestone and gravel aggregates, and different asphalt binders.

8. KEYWORDS

8.1. Asphalt; binder; cutback; cylindrical specimens; Marshall apparatus; mixtures; plastic flow; stability.

9. REFERENCES


9.3. AASHTO. T 166, Bulk Specific Gravity ($G_{mb}$) of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens.

9.4. AASHTO. T 275, Bulk Specific Gravity ($G_{mb}$) of Compacted Asphalt Mixtures Using Paraffin-Coated Specimens.

9.5. AASHTO. T 331, Bulk Specific Gravity ($G_{mb}$) and Density of Compacted Asphalt Mixtures Using Automatic Vacuum Sealing Method.
Standard Practice for Reducing Samples of Aggregate to Testing Size

This standard is issued under the fixed designation C702/C702M; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This practice covers three methods for the reduction of large samples of aggregate to the appropriate size for testing. These techniques are intended to minimize variations in measured characteristics between the test samples selected and the large sample.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

NOTE 1—Sieve size is identified by its standard designation in Specification E11. The alternative designation given in parentheses is for information only and does not represent a different standard sieve size.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.

1.4 This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 ASTM Standards:

C128 Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate
D75 Practice for Sampling Aggregates
E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. Terminology

3.1 Definitions—The terms used in this practice are defined in Terminology C125.

4. Significance and Use

4.1 Specifications for aggregates require obtaining representative portions of the supply material for testing. Other factors being equal, larger samples will tend to be more representative of the total supply. This practice provides procedures for reducing the large sample obtained in the field, or produced in the laboratory, to a convenient size for conducting a number of descriptive and quality tests. Failure to carefully follow the procedures in this practice could result in providing a non-representative sample to be used in subsequent testing. The individual test methods provide for minimum amount of material to be tested.

4.2 Under certain circumstances, reduction in size of the large sample prior to testing is not recommended. Substantial differences between the selected test samples sometimes cannot be avoided, for example, in the case of an aggregate having relatively few large size particles in the sample. The laws of chance dictate that these few particles may be unequally distributed among the reduced size test samples. Similarly, if the test sample is being examined for certain contaminants occurring in only small percentages, caution should be used in interpreting results from the reduced size test sample. Chance inclusion or exclusion of only one or two particles in the selected test sample may importantly influence interpretation of the characteristics of the original sample. In these cases, the entire original sample should be tested.

5. Selection of Method

5.1 Fine Aggregate—Reduce the size of samples of fine aggregate that are drier than the saturated-surface-dry condition (Note 2) using a mechanical splitter according to Method
A. Reduce the size of samples having free moisture on the particle surfaces by quartering according to Method B, or by treating as a miniature stockpile as described in Method C.

5.1.1 If the use of Method B or Method C is desired, and the sample does not have free moisture on the particle surfaces, moisten the sample to obtain free moisture on the particle surfaces, mix thoroughly, and then reduce the sample size.

5.1.2 If use of Method A is desired and the sample has free moisture on the particle surfaces, dry the entire sample to at least the saturated-surface-dry condition, using temperatures that do not exceed those specified for any of the tests contemplated, and then reduce the sample size. Alternatively, if the moist sample is very large, make a preliminary split using a mechanical splitter having chute openings of 38 mm [1 1/2 in.] or more in width to reduce the sample to not less than 5 kg [10 lb]. Dry the portion so obtained, and reduce it to test sample size using Method A.

NOTE 2—The method of determining the saturated-surface-dry condition is described in Test Method C128. As a quick approximation, if the fine aggregate will retain its shape when molded in the hand, it may be considered to be wetter than saturated-surface-dry.

5.2 Coarse Aggregates and Mixtures of Coarse and Fine Aggregates—Reduce the sample using a mechanical splitter in accordance with Method A (preferred method) or by quartering in accordance with Method B. The miniature stockpile Method C is not permitted for coarse aggregates or mixtures of coarse and fine aggregates.

6. Sampling

6.1 Obtain samples of aggregate in the field in accordance with Practice D75, or as required by individual test methods. When tests for sieve analysis only are contemplated, the size of the field sample listed in Practice D75 is usually adequate. When additional tests are to be conducted, the user shall be satisfied that the initial size of the field sample is adequate to accomplish all intended tests. Use similar procedures for aggregate produced in the laboratory.

METHOD A—MECHANICAL SPLITTER

7. Apparatus

7.1 Sample Splitter—Sample splitters shall have an even number of equal width chutes, but not less than a total of eight for coarse aggregate, or twelve for fine aggregate, which discharge alternately to each side of the splitter. For coarse aggregate and mixed aggregate, the minimum width of the individual chutes shall be approximately 50 % larger than the largest particles in the sample to be split (Note 3). For dry fine aggregate in which the entire sample will pass the 9.5-mm (3/8-in.) sieve, a splitter having chutes 12.5 to 20 mm [1/2 to 3/4 in.] wide shall be used. The splitter shall be equipped with a minimum of two receptacles to hold the two halves of the sample following splitting. It shall also be equipped with a hopper or straight-edged pan which has a width equal to or slightly less than the overall width of the chute assembly, by which the sample may be fed at a controlled rate to the chutes. The splitter and accessory equipment shall be so designed that the sample will flow smoothly without restriction or loss of material (see Fig. 1 and Fig. 2).

NOTE 3—Mechanical splitters are commonly available in sizes adequate for coarse aggregate having the largest particle not over 50.0 mm [2 in.].

8. Procedure

8.1 Place the original sample in the hopper or pan and uniformly distribute it from edge to edge, so that when it is introduced into the chutes, approximately equal amounts will flow through each chute. Introduce the sample at a rate so as to allow it to flow freely through the chutes and into the receptacles below. Reintroduce the portion of the sample in one of the receptacles into the splitter as many times as necessary,
alternating each side, to reduce the sample to the size specified for the intended test. Reserve the portion of material collected in the other receptacle for reduction in size for other tests, when required.

**METHOD B—QUARTERING**

9. **Apparatus**

9.1 Apparatus shall consist of a straight-edged scoop, shovel, or trowel; a broom or brush; and a canvas blanket approximately 2 by 2.5 m [6 by 8 ft].

10. **Procedure**

10.1 Use either the procedure described in 10.1.1 or 10.1.2 or a combination of both.

10.1.1 Place the original sample on a hard, clean, level surface where there will be neither loss of material nor the accidental addition of foreign material. Mix the material thoroughly by turning the entire sample over three times. With the last turning, shovel the entire sample into a conical pile by depositing each shovelful on top of the preceding one. Carefully flatten the conical pile to a uniform thickness and diameter by pressing down the apex with a shovel so that each quarter sector of the resulting pile will contain the material originally in it. The diameter should be approximately four to eight times the thickness. Divide the flattened mass into four equal quarters with a shovel or trowel and remove two diagonally opposite quarters, including all fine material, and brush the cleared spaces clean. Successively mix and quarter the remaining material until the sample is reduced to the desired size (Fig. 3).

10.1.2 As an alternative to the procedure described in 10.1.1, when the floor surface is uneven, place the field sample on a canvas blanket and mix with a shovel as described in 10.1.1, or by alternately lifting each corner of the canvas and pulling it over the sample toward the diagonally opposite corner causing the material to be rolled. Flatten the pile as described in 10.1.1. Divide the sample as described in 10.1.1, or if the surface beneath the blanket is uneven, insert a stick or pipe beneath the blanket and under the center of the pile, then lift both ends of the stick, dividing the sample into two equal parts. Remove the stick leaving a fold of the blanket between the divided portions. Insert the stick under the center of the pile at right angles to the first division and again lift both ends of the stick, dividing the sample into four equal parts. Remove two diagonally opposite quarters, being careful to clean the fines from the blanket. Successively mix and quarter the remaining material until the sample is reduced to the desired size (Fig. 4).

**METHOD C—MINIATURE STOCKPILE SAMPLING**

(DAMP FINE AGGREGATE ONLY)

11. **Apparatus**

11.1 Apparatus shall consist of a straight-edged scoop, shovel, or trowel for mixing the aggregate, and either a small sampling thief, small scoop, or spoon for sampling.

12. **Procedure**

12.1 Place the original sample of damp fine aggregate on a hard clean, level surface where there will be neither loss of material nor the accidental addition of foreign material. Mix the material thoroughly by turning the entire sample over three times. With the last turning, shovel the entire sample into a conical pile by depositing each shovelful on top of the preceding one. If desired, flatten the conical pile to a uniform thickness and diameter by pressing down the apex with a shovel so that each quarter sector of the resulting pile will contain the material originally in it. Obtain a sample for each test by selecting at least five increments of material at random.
locations around the miniature stockpile, using any of the sampling devices described in 11.1.

13. Keywords

13.1 aggregate; aggregate—coarse; aggregate—fine; field testing—aggregate; sampling—aggregates; sample reduction; specimen preparation
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Standard Method of Test for

Total Evaporable Moisture Content of Aggregate by Drying

AASHTO Designation: T 255-00 (2017)\textsuperscript{1}

Technical Section: 1c, Aggregates

Release: Group 3 (August)

ASTM Designation: C566-13
Standard Method of Test for

Total Evaporable Moisture Content of Aggregate by Drying

AASHTO Designation: T 255-00 (2017)

Technical Section: 1c, Aggregates

Release: Group 3 (August)

ASTM Designation: C566-13

1. SCOPE

1.1. This test method covers the determination of the percentage of evaporable moisture in a sample of aggregate by drying both surface moisture and moisture in the pores of the aggregate. Some aggregate may contain water that is chemically combined with the minerals in the aggregate. Such water is not evaporable and is not included in the percentage determined by this test method.

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

1.3. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to its use. For specific precautionary statements, see Sections 5.3.1, 7.2.1, and 7.3.1.

2. REFERENCED DOCUMENTS

2.1. AASHTO Standards:

- M 231, Weighing Devices Used in the Testing of Materials
- R 90, Sampling Aggregate Products
- T 19M/T 19, Bulk Density (“Unit Weight”) and Voids in Aggregate
- T 84, Specific Gravity and Absorption of Fine Aggregate
- T 85, Specific Gravity and Absorption of Coarse Aggregate

2.2. ASTM Standards:

- C125, Standard Terminology Relating to Concrete and Concrete Aggregates
- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- E11, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves

2.3. Other Document:

- National Research Council Report SHRP-P-619
3. TERMINOLOGY

3.1. Definitions—For definitions of terms used in this test method, refer to ASTM C125.

4. SIGNIFICANCE AND USE

4.1. This test method is sufficiently accurate for usual purposes such as adjusting batch quantities of ingredients for concrete. It will generally measure the moisture in the test sample more reliably than the sample can be made to represent the aggregate supply. In rare cases where aggregate itself is altered by heat, or where more refined measurement is required, the test should be conducted using a ventilated, controlled-temperature oven.

4.2. Large particles of coarse aggregate, especially those larger than 50 mm (2 in.), will require greater time for the moisture to travel from the interior of the particle to the surface. The user of this test method should determine by trial if rapid drying methods provide sufficient accuracy for the intended use when drying large-size particles.

5. APPARATUS

5.1. 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.

5.2. Source of Heat—A ventilated oven capable of maintaining the temperature surrounding the sample at 110 ± 5°C (230 ± 9°F). Where close control of the temperature is not required (see Section 4.1), other suitable sources of heat may be used, such as an electric or gas hot plate, electric heat lamps, or a ventilated microwave oven.

5.3. Sample Container—A container not affected by the heat, and of sufficient volume to contain the sample without danger of spilling, and of such shape that the depth of sample will not exceed one-fifth of the least lateral dimension.

5.3.1. Precaution—When a microwave oven is used, the container shall be nonmetallic.

Note 1—Except for testing large samples, an ordinary frying pan is suitable for use with a hot plate, or any shallow flat-bottomed metal pan with heat lamps or oven. Note precaution in Section 5.3.1.

5.4. Stirrer—A metal spoon or spatula of convenient size.

6. SAMPLE

6.1. Sampling shall generally be accomplished in accordance with R 90, except the sample size may be as stated in Table 1.
Table 1—Sample Size for Aggregate

<table>
<thead>
<tr>
<th>Nominal Maximum Size of Aggregate, mm (in.)</th>
<th>Mass of Normal Weight Aggregate Sample, Min., kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75 (0.187) (No. 4)</td>
<td>0.5</td>
</tr>
<tr>
<td>9.5 (3/8)</td>
<td>1.5</td>
</tr>
<tr>
<td>12.5 (1/2)</td>
<td>2</td>
</tr>
<tr>
<td>19.0 (3/8)</td>
<td>3</td>
</tr>
<tr>
<td>25.0 (1)</td>
<td>4</td>
</tr>
<tr>
<td>37.5 (1 1/2)</td>
<td>6</td>
</tr>
<tr>
<td>50 (2)</td>
<td>8</td>
</tr>
<tr>
<td>63 (2 1/2)</td>
<td>10</td>
</tr>
<tr>
<td>75 (3)</td>
<td>13</td>
</tr>
<tr>
<td>90 (3 1/2)</td>
<td>16</td>
</tr>
<tr>
<td>100 (4)</td>
<td>25</td>
</tr>
<tr>
<td>150 (6)</td>
<td>50</td>
</tr>
</tbody>
</table>

*a* Based on sieves meeting ASTM E11.

*b* Determine the minimum sample mass for lightweight aggregate by multiplying the value listed by the dry-loose unit mass of the aggregate in kg/m³ (determined using T 19M/T 19) and dividing by 1600.

6.2. Secure a sample of the aggregate representative of the moisture content in the supply being tested and having a mass not less than the amount listed in Table 1. Protect the sample against loss of moisture prior to determining the mass.

7. **PROCEDURE**

7.1. Determine the mass of the sample to the nearest 0.1 percent.

7.2. Dry the sample thoroughly in the sample container by means of the selected source of heat, exercising care to avoid loss of any particles. Very rapid heating may cause some particles to explode, resulting in loss of particles. Use a controlled temperature oven when excessive heat may alter the character of the aggregate, or where more precise measurement is required. If a source of heat other than the controlled temperature oven is used, stir the sample during drying to accelerate the operation and avoid localized overheating. When using a microwave oven, stirring of the sample is optional.

7.2.1. **Caution:** When using a microwave oven, occasionally minerals are present in aggregates that may cause the material to overheat and explode. If this occurs, it can damage the microwave oven.

7.3. When a hot plate is used, drying can be expedited by the following procedure. Add sufficient anhydrous denatured alcohol to cover the moist sample. Stir and allow suspended material to settle. Decant as much of the alcohol as possible without losing any of the sample. Ignite the remaining alcohol and allow it to burn off during drying over the hot plate.

7.3.1. **Warning:** Exercise care to control the ignition operation to prevent injury or damage from the burning alcohol.

7.4. The sample is thoroughly dry when further heating causes, or would cause, less than 0.1 percent additional loss in mass.

7.5. Determine the mass of the dried sample to the nearest 0.1 percent after it has cooled sufficiently not to damage the balance.
8. **CALCULATION**

8.1. Calculate total evaporable moisture content as follows:

\[
p = 100 \left( \frac{W - D}{D} \right)
\]

where:

- \(p\) = total evaporable moisture content of sample, percent;
- \(W\) = mass of original sample, g; and
- \(D\) = mass of dried sample, g.

8.2. Surface moisture content is equal to the difference between the total evaporable moisture content and the absorption, with all values based on the mass of a dry sample. Absorption may be determined in accordance with T 85, Test for Specific Gravity and Absorption of Coarse Aggregate, or T 84, Test for Specific Gravity and Absorption of Fine Aggregate.

9. **PRECISION AND BIAS**

9.1. **Precision:**

9.1.1. The within-laboratory single-operator standard deviation for moisture content of aggregates has been found to be 0.28 percent (Note 2). Therefore, results of two properly conducted tests by the same operator in the same laboratory on the same type of aggregate sample should not differ by more than 0.79 percent (Note 2) from each other.

9.1.2. The between-laboratory standard deviation for moisture content of aggregates has been found to be 0.28 percent (Note 2). Therefore, results of properly conducted tests from two laboratories on the same aggregate sample should not differ by more than 0.79 percent (Note 2) from each other.

9.1.3. Test data used to derive the above precision indices were obtained from samples dried to a constant mass in a drying oven maintained at 110 ± 5°C. When other drying procedures are used, the precision of the results may be significantly different than that indicated above.

**Note 2**—These numbers represent, respectively, the 1s and d2s limits as described in ASTM C670.

9.2. **Bias:**

9.2.1. When experimental results are compared with known values from accurately compounded specimens, the following has been derived.

9.2.1.1. The bias of moisture tests on one aggregate material has been found to have a mean of +0.06 percent. The bias of individual test values from the same aggregate material has been found with 95 percent confidence to lie between −0.07 percent and +0.20 percent.

9.2.1.2. The bias of moisture tests on a second aggregate material has been found to have a mean of less than +0.01 percent. The bias of individual test values from the same aggregate material has been found with 95 percent confidence to lie between −0.14 percent and +0.14 percent.

9.2.1.3. The bias of moisture tests overall on both aggregate materials has been found to have a mean of +0.03 percent. The bias of individual test values overall from both aggregate materials has been found with 95 percent confidence to lie between −0.12 percent and +0.18 percent.
9.2.2. Test data used to derive the above bias statement were obtained from samples dried to a constant mass in a drying oven maintained at 110 ± 5°C. When other drying procedures are used, the bias of the results may be significantly different than that indicated above.

Note 3—These precision and bias statements were derived from aggregate moisture data provided by 17 laboratories participating in the SHRP Soil Moisture Proficiency Sample Program, which is fully described in the National Research Council Report SHRP-P-619. The samples tested that relate to these statements were well-graded mixtures of fine and coarse aggregate with moisture contents ranging from air dry to saturated surface-dry.

10. KEYWORDS

10.1. Aggregate; drying; moisture content.

1 This method is technically equivalent to ASTM C566-13, except for the balance statement in Section 5.1.
Standard Method of Test for

Percent Air Voids in Compacted Dense and Open Asphalt Mixtures

AASHTO Designation: T 269-14 (2018)\(^1\)
Technical Section: 2c, Asphalt–Aggregate Mixtures
Release: Group 3 (August)
ASTM Designation: D3203/D3203M-11
Standard Method of Test for

Percent Air Voids in Compacted Dense and Open Asphalt Mixtures

AASHTO Designation: T 269-14 (2018)¹
Technical Section: 2c, Asphalt–Aggregate Mixtures
Release: Group 3 (August)
ASTM Designation: D3203/D3203M-11

1. SCOPE

1.1. This method covers the determination of the percent air voids \((P_a)\) in compacted dense and open asphalt mixtures.

1.2. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns 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:
   - T 166, Bulk Specific Gravity \((G_{mb})\) of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens
   - T 209, Theoretical Maximum Specific Gravity \((G_{mm})\) and Density of Hot Mix Asphalt (HMA)
   - T 275, Bulk Specific Gravity \((G_{mb})\) of Compacted Asphalt Mixtures Using Paraffin-Coated Specimens
   - T 331, Bulk Specific Gravity \((G_{mb})\) and Density of Compacted Asphalt Mixtures Using Automatic Vacuum Sealing Method

2.2. ASTM Standards:
   - D3549/D3549M-11, Standard Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens
   - D4460, Standard Practice for Calculating Precision Limits Where Values are Calculated from Other Test Methods
   - E1547, Standard Terminology Relating to Industrial and Specialty Chemicals

3. TERMINOLOGY

3.1. The terms specific gravity and density used in this test method are in accordance with ASTM E1547.
3.2. **Definitions:**

3.2.1. *air voids* ($P_a$)—the pockets of air between the asphalt-coated aggregate particles in a compacted asphalt mixture.

3.2.2. *dense asphalt mixture*—asphalt mixtures in which the air voids ($P_a$) are less than 10 percent when compacted.

3.2.3. *open asphalt mixture*—asphalt mixtures in which the air voids ($P_a$) are 10 percent or more when compacted.

3.2.3.1. For borderline cases, an asphalt mixture shall be designated as an open asphalt mixture if the calculated percent air voids ($P_a$), based on either Section 6.1 or 6.2, are 10 percent or more.

4. **SIGNIFICANCE AND USE**

4.1. The percent air voids ($P_a$) in an asphalt mixture is used as one of the criteria in the design methods and for evaluation of the compaction achieved on asphalt paving projects.

5. **SAMPLING**

5.1. Samples for testing shall consist of specimens from laboratory-molded mixtures or cores from field-compacted mixtures.

6. **PROCEDURE**

6.1. For dense asphalt mixtures, determine the bulk specific gravity ($G_{mb}$) of the compacted mixture by either T 166, T 275, or T 331. Determine the theoretical maximum specific gravity ($G_{mm}$) in accordance with T 209 on a comparable asphalt mixture to avoid the influence of differences in gradation, asphalt content, etc.

6.2. For open asphalt mixtures, use either of the following methods:

6.2.1. *Automatic Vacuum Sealing Method*—Determine the bulk specific gravity ($G_{mb}$) of the compacted mixture by T 331. Determine the theoretical maximum specific gravity ($G_{mm}$) in accordance with T 209 on a comparable asphalt mixture to avoid the influence of differences in gradation, asphalt content, etc.

6.2.2. *Volume Method*—Determine the density of a regularly shaped specimen of compacted mixture from its dry mass (in grams) and its volume (in cubic centimeters). Obtain the height of the specimen by ASTM D3549/D3549M. Measure the diameter of the specimen at four locations, and average the measurements. Calculate the volume of the specimen based on the average height and diameter measurement. Convert the density to bulk specific gravity ($G_{mb}$) by dividing by 0.99707 g/cm$^3$ or 997 kg/m$^3$, the density of water at 25°C (77°F). Determine the theoretical maximum specific gravity ($G_{mm}$) in accordance with T 209 on a comparable asphalt mixture to avoid the influence of differences in gradation, asphalt content, etc.

For reference purposes, determine both the bulk specific gravity ($G_{mb}$) and the theoretical maximum specific gravity ($G_{mm}$) on portions of the same sample of compacted asphalt mixture.
7. CALCULATIONS

7.1. Calculate the percent air voids ($P_a$) in a compacted asphalt mixture as follows:

$$P_a = 100 \left( 1 - \frac{G_{mb}}{G_{mm}} \right)$$

or

$$P_a = 100 \left( \frac{G_{mm} - G_{mb}}{G_{mm}} \right)$$

where:

$G_{mb} = \text{the bulk specific gravity; and}$

$G_{mm} = \text{the theoretical maximum specific gravity.}$

7.2. Report the percent air voids ($P_a$) to one decimal place.

8. PRECISION AND BIAS

8.1. The precision of this test method depends on the precision of test methods for bulk specific gravity ($G_{mb}$) and theoretical maximum specific gravity ($G_{mm}$). It is computed by a procedure described in ASTM D4460. Because the computation for percent air voids ($P_a$) in Section 7.1 involves the quotient of bulk specific gravity ($G_{mb}$) divided by the theoretical maximum specific gravity ($G_{mm}$), the quotient formula is used:

$$\sigma_{x/y} = \sqrt{\frac{\bar{y}^2 \sigma_x^2 + \bar{x}^2 \sigma_y^2}{\bar{y}^4}}$$

where:

$\sigma_{x/y} = \text{the standard deviation for determining the precision limits of test results for a standard based on the quotient of two test results from two other standards;}$

$\bar{x} = \text{the mean (average) value of the } x \text{ standard [bulk specific gravity } (G_{mb}) \text{]} \text{ test results;}$

$\bar{y} = \text{the mean (average) value of the } y \text{ standard [theoretical maximum specific gravity } (G_{mm}) \text{]} \text{ test results;}$

$\sigma_x = \text{the standard deviation from the precision statement of the } x \text{ standard; and}$

$\sigma_y = \text{the standard deviation from the precision statement of the } y \text{ standard.}$

**Note 1**—The $x$ standard (T 166, T 275, or T 331) is used to compute bulk specific gravity ($G_{mb}$), and the $y$ standard (T 209) is used to compute theoretical maximum specific gravity ($G_{mm}$).

8.2. Criteria for judging the acceptability of percent air voids ($P_a$) test results that are obtained by using $x$ standard and $y$ standard for nonporous aggregates are:
9. KEYWORDS

9.1. Air voids; bulk specific gravity; dense asphalt mixture; maximum specific gravity; open asphalt mixture.

APPENDIX

(Nonmandatory Information)

X1. EXAMPLE CALCULATION OF PRECISION

X1.1. Assume the following precision data:

Bulk specific gravity \((G_{mb})\), \(x\)
When the average of \(x = 2.423\) and the standard deviation of \(x = 0.007\).

Theoretical maximum specific gravity \((G_{mm})\), \(y\)
When the average of \(y = 2.523\) and the standard deviation of \(y = 0.004\).

Then using Equation 2:

\[
\sigma_{x/y} = \sqrt{\frac{(2.523)^2 (0.007)^2 + (2.423)^2 (0.004)^2}{(2.523)^4}} = 0.00316 \quad (X1.1)
\]

This value is in terms of air voids \((P_a)\); therefore, the value should be multiplied by 100 to convert it into a percentage. Therefore:

\[
\sigma_{x/y} = 0.0032 \times 100 = 0.32% \quad (X1.2)
\]

1 Similar, but not technically identical to ASTM D3203/D3203M-11.
Standard Method of Test for

Determination of Draindown Characteristics in Uncompacted Asphalt Mixtures

AASHTO Designation: T 305-14 (2018)
Technical Section: 2c, Asphalt–Aggregate Mixtures
Release: Group 3 (August)
Standard Method of Test for

Determination of Draindown Characteristics in Uncompacted Asphalt Mixtures

AASHTO Designation: T 305-14 (2018)

Technical Section: 2c, Asphalt–Aggregate Mixtures

Release: Group 3 (August)

1. SCOPE

1.1. This test method covers the determination of the amount of draindown material in an uncompacted asphalt mixture sample when the sample is held at elevated temperatures comparable to those encountered during the production, storage, transport, and placement of the mixture. The test is particularly applicable to mixtures such as porous asphalt (open-graded friction course) and Stone Matrix Asphalt (SMA).

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

1.3. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns 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:
- R 47, Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size
- T 255, Total Evaporable Moisture Content of Aggregate by Drying

2.2. ASTM Standard:
- E11, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. TERMINOLOGY

3.1. Definitions:

3.1.1. draindown material—For the purpose of this test method, draindown material is considered to be that portion of material that separates itself from the sample as a whole and is deposited outside the wire basket during the test. The draindown material may be composed of either asphalt binder or a combination of asphalt binder and fine aggregate.

3.1.2. draindown—The process by which draindown material separates itself from the sample as a whole.
4. SUMMARY OF METHOD

4.1. A sample of the asphalt mixture to be tested is prepared in the laboratory or obtained from field production. The sample is placed in a wire basket, which is positioned on a plate or other suitable container of known mass. The sample, basket, and plate or container are placed in a forced-draft oven for 1 h at a preselected temperature. At the end of 1 h, the basket containing the sample is removed from the oven, along with the plate or container and the mass of the plate or container is determined. The amount of draindown material is then calculated.

5. SIGNIFICANCE AND USE

5.1. This test method can be used to determine whether the amount of draindown material measured for a given asphalt mixture is within acceptable levels. The test provides an evaluation of the draindown potential of an asphalt mixture during mixture design or during field production. This test is primarily used for mixtures with high coarse aggregate content such as porous asphalt (open-graded friction course) and SMA.

6. APPARATUS

6.1. Forced-Draft Oven—Capable of maintaining the temperature in a range from 120 to 175°C (250 to 350°F). The oven should maintain the set temperature to within ±2°C (±3.6°F).

6.2. Plates—Or other suitable containers of appropriate size. The plates or containers used should be of appropriate durability to withstand the oven temperatures. Cake pans or pie tins are examples of suitable types of containers.

6.3. Standard Basket—Meeting the dimensions shown in Figure 1. The basket shall be constructed using standard 6.3-mm (0.25-in.) sieve cloth as specified in ASTM E11.

6.4. Balance—Accurate to 0.1 g.

6.5. Other apparatus—Spatulas, trowels, bowls, and mixer as needed.

7. SAMPLE PREPARATION

7.1. Laboratory-Prepared Samples:

7.1.1. Number of Samples—For each mixture tested, the draindown characteristics should be determined at two different temperatures. The two temperatures should be the anticipated plant production temperature, as well as 15°C (27°F) above that temperature (Note 1). For each temperature, duplicate samples should be tested. Thus for one asphalt mixture, a minimum of four samples will be tested.

Note 1—When using the test as part of the mixture design procedure, the test should be performed at two temperatures in order to determine the potential effect that plant temperature variation may have on the mixture during production. When the test is used in the field during production, it should be necessary to perform the test at the plant production temperature only.

7.1.2. Dry the aggregate to a constant mass in accordance with T 255, and sieve it into the appropriate size fractions as indicated in T 245.

7.1.3. Determine the anticipated plant production temperature or select a mixing temperature in accordance with T 245.
7.1.4. Place into separate pans for each test sample the amount of each size fraction required to produce completed mixture samples having a mass of 1200 ± 200 g. The aggregate fractions shall be combined such that the resulting aggregate blend has the same gradation as the job mix formula. Place the aggregate samples in an oven and heat them to a temperature not to exceed the mixing temperature established in Section 7.1.3 by more than approximately 28°C (50°F).

7.1.5. Heat the asphalt binder to the temperature established in Section 7.1.3.

Figure 1—Wire Basket Assembly
7.1.6. Place the heated aggregate in the mixing bowl. Add any stabilizers (Note 2) and thoroughly mix the dry components. Form a crater in the aggregate blend and add the required amount of asphalt binder. The amount of asphalt binder shall be such that the final sample has the same asphalt content as the job mix formula. At this point, the temperature of the aggregate and asphalt binder shall be within the limits of the mixing temperature established in Section 7.1.3. Using a spatula (if mixing by hand) or a mixer, mix the aggregate (and stabilizer, if any) and asphalt binder quickly until the aggregate is thoroughly coated.

**Note 2**—Some types of stabilizers, such as fibers or some polymers, must be added directly to the aggregate prior to mixing with the asphalt binder. Other types of stabilizers must be added directly to the asphalt binder prior to blending with the aggregate.

7.2. *Plant-Produced Samples:*

7.2.1. *Number of Samples*—For plant-produced samples, duplicate samples should be tested at the plant production temperature.

7.2.2. Samples may be obtained during plant production by sampling the mixture at any appropriate location, such as the trucks prior to the mixture leaving the plant. Samples obtained during actual production should be reduced to the proper test sample size by R 47.

**Note 3**—Caution should be exercised when sampling from surge or storage bins because draindown may already have taken place.

8. **PROCEDURE**

8.1. Transfer the hot laboratory-produced or plant-produced uncompacted mixture sample to a tared wire basket as described in Section 6.3. Place the entire sample in the wire basket. Do not consolidate or otherwise disturb the sample after transferring it to the basket. Determine the mass of the sample to the nearest 0.1 g. Care should be exercised to ensure that the sample does not cool more than 25°C (77°F) below the test temperature. (See Section 8.2.)

8.2. Determine and record the mass of a plate or other suitable container to the nearest 0.1 g. Place the basket on the plate or container and place the assembly into the oven at the temperature as determined in Section 7.1.1 or 7.2.1 for 60 ± 5 min. If the sample has cooled more than 25°C (77°F) below the test temperature, the test should be conducted for 70 ± 5 min.

8.3. After the sample has been in the oven for the time specified in Section 8.2, remove the basket and plate or container from the oven. Determine and record the mass of the plate or container plus draindown material to the nearest 0.1 g.

9. **CALCULATIONS**

9.1. Calculate the percent of mixture that drained by subtracting the initial plate or container mass from the final plate or container mass and dividing this value by the initial total sample mass. Multiply the result by 100 to obtain a percentage.

\[
\frac{M_f - M_i}{M_t} \times 100 = \text{percent of mixture that drained or percent draindown}
\]

where:

- \(M_f\) = final plate or container mass;
- \(M_i\) = initial plate or container mass; and
- \(M_t\) = initial total sample mass.
10. REPORT

10.1. Report the average percent draindown (average percent of mixture that drained) at each of the test temperatures.

11. KEYWORDS

11.1. Asphalt mixture; draindown; fiber; open-graded friction course; porous asphalt; SMA; stabilizer.
Standard Method of Test for

Determining the Asphalt Binder Content of Asphalt Mixtures by the Ignition Method

AASHTO Designation: T 308-18
Technical Section: 2c, Asphalt–Aggregate Mixtures
Release: Group 3 (August)
Standard Method of Test for

**Determining the Asphalt Binder Content of Asphalt Mixtures by the Ignition Method**

AASHTO Designation: T 308-18

Technical Section: 2c, Asphalt–Aggregate Mixtures

Release: Group 3 (August)

1. **SCOPE**

1.1. This test method covers the determination of asphalt binder content of asphalt mixtures by ignition at temperatures that reach the flashpoint of the binder in a furnace. The means of specimen heating may be the convection method or the direct infrared (IR) irradiation method. The aggregate remaining after burning can be used for sieve analysis using T 30.

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

1.3. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to consult and 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
- R 47, Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size
- R 66, Sampling Asphalt Materials
- R 76, Reducing Samples of Aggregate to Testing Size
- R 90, Sampling Aggregate Products
- T 30, Mechanical Analysis of Extracted Aggregate
- T 168, Sampling Bituminous Paving Mixtures
- T 329, Moisture Content of Asphalt Mixtures by Oven Method

2.2. *ASTM Standard:*

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

2.3. *Other Documents:*

- Manufacturer’s Instruction Manual
- NCHRP Final Report, NCHRP Project No. 9-26, Phase 3
3. SUMMARY OF TEST METHOD

3.1. The asphalt binder in the asphalt mixture is ignited using the furnace equipment applicable to the particular method. This procedure covers two methods. Method A requires an ignition furnace with an internal balance. Method B requires an ignition furnace with an external balance.

3.2. The asphalt binder content is calculated as the difference between the initial mass of the asphalt mixture and the mass of the residual aggregate, with adjustments for an asphalt binder correction factor and the moisture content. The asphalt binder content is expressed as a mass percent of the moisture-free mixture. This method may be affected by the type of aggregate in the mixture. Accordingly, to optimize accuracy, correction factors for asphalt binder and aggregate will be established by testing a set of correction factor specimens for each type of asphalt mixture. Correction factors must be determined before any acceptance testing is performed.

4. SIGNIFICANCE AND USE

4.1. This method can be used for quantitative determinations of asphalt binder content and gradation in asphalt mixture and pavement specimens for quality control, specification acceptance, and mixture evaluation studies. This method does not require the use of solvents. Aggregate obtained by this test method may be used for gradation analysis according to T 30.

5. APPARATUS

5.1. Ignition Furnace—A forced-air ignition furnace that heats the specimens by either the convection or direct IR irradiation method. The convection-type furnace must be capable of maintaining a temperature of 538 ± 5°C (1000 ± 9°F). The furnace chamber dimensions shall be adequate to accommodate a specimen size of 3500 g. The furnace door shall be equipped so that the door cannot be opened during the ignition test. A method for reducing furnace emissions shall be provided. The furnace shall be vented into a hood or to the outside and, when set up properly, shall have no noticeable odors escaping into the laboratory. The furnace shall have a fan capable of pulling air through the furnace to expedite the test and reduce the escape of smoke into the laboratory.

5.1.1. For Method A, the furnace shall also have an internal balance thermally isolated from the furnace chamber and accurate to 0.1 g. The balance shall be capable of weighing a 3500-g specimen in addition to the specimen baskets. A data collection system will be included so that the mass can be automatically determined and displayed during the test. The furnace shall have a built-in computer program to calculate the change in mass of the specimen baskets and provide for the input of a correction factor for aggregate loss. The furnace shall provide a printed ticket with the initial specimen mass, specimen mass loss, temperature compensation, correction factor, corrected asphalt binder content (percent), test time, and test temperature. The furnace shall provide an audible alarm and indicator light when the specimen mass loss does not exceed 0.01 percent of the total specimen mass for 3 consecutive min. The furnace shall also allow the operator to change the ending mass loss percentage to 0.02 percent.

5.2. Specimen Basket Assembly—Consisting of specimen basket(s), catch pan, and an assembly guard to secure the specimen basket(s) to the catch pan.

5.2.1. Specimen Basket(s)—Of appropriate size to allow the specimens to be thinly spread and allow air to flow through and around the specimen particles. Sets with two or more baskets shall be nested. The specimen shall be completely enclosed with screen mesh, perforated stainless steel plate, or other suitable material.
Note 1—Screen mesh or other suitable material with maximum and minimum openings of 2.36 mm (No. 8) and 0.600 mm (No. 30), respectively, has been found to perform well.

5.2.2. Catch Pan—Of sufficient size to hold the specimen basket(s) so that aggregate particles and melting asphalt binder falling through the screen are caught.

5.3. Oven—Capable of maintaining 110 ± 5°C (230 ± 9°F).

5.4. Balance—Of sufficient capacity and conforming to the requirements of M 231, Class G 2.

5.5. Safety Equipment—Safety glasses or face shield, dust mask, high-temperature gloves, long-sleeved jacket, a heat-resistant surface capable of withstanding 650°C (1202°F), and a protective cage capable of surrounding the specimen baskets during the cooling period.

5.6. Miscellaneous Equipment—A pan larger than the specimen basket(s) for transferring the specimen after ignition, spatulas, bowls, and wire brushes.

6. SAMPLING

6.1. Obtain samples of freshly produced asphalt mixture in accordance with T 168.

6.2. The specimen shall be the end result of reducing a larger sample in accordance with R 47.

6.3. If the mixture is not sufficiently soft to separate with a spatula or trowel, place it in a large, flat pan in an oven at 110 ± 5°C (230 ± 9°F) until it is workable. Do not leave the specimen in the oven for an extended period of time. Excessive heating may cause detrimental effects such as asphalt draindown or oxidation.

6.4. The size of the test specimen shall be governed by the nominal-maximum aggregate size of the asphalt mixture and shall conform to the mass requirement shown in Table 1. When the mass of the specimen exceeds the capacity of the equipment used, the specimen may be divided into suitable increments, tested, and the results appropriately combined for calculation of the asphalt binder content (using a weighted average). Specimen sizes shall not be more than 500 g greater than the minimum recommended specimen mass.

Note 2—Large specimens of fine mixes tend to result in incomplete ignition of asphalt binder.

Table 1—Mass Requirements

<table>
<thead>
<tr>
<th>Nominal-Maximum Aggregate Size, a mm</th>
<th>Sieve Size</th>
<th>Minimum Mass of Specimen, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75</td>
<td>No. 4</td>
<td>1200</td>
</tr>
<tr>
<td>9.5</td>
<td>3/8 in.</td>
<td>1200</td>
</tr>
<tr>
<td>12.5</td>
<td>1/2 in.</td>
<td>1500</td>
</tr>
<tr>
<td>19.0</td>
<td>3/4 in.</td>
<td>2000</td>
</tr>
<tr>
<td>25.0</td>
<td>1 in.</td>
<td>3000</td>
</tr>
<tr>
<td>37.5</td>
<td>1 1/2 in.</td>
<td>4000</td>
</tr>
</tbody>
</table>

a Nominal-maximum aggregate size—one size larger than the first sieve to retain more than 10 percent.
TEST METHOD A—INTERNAL BALANCE

7. TEST PROCEDURES

7.1. Test Initiation:

7.1.1. For the convection-type furnace, preheat the ignition furnace to 538 ± 5°C (1000 ± 9°F) or to the temperature determined by the correction factor process in the Annex. Manually record the furnace temperature (set point) prior to the initiation of the test if the furnace does not record automatically.

7.1.2. For the direct IR irradiation-type furnace, use the same burn profile as used during the correction factor determination.

7.2. Oven dry the asphalt mixture specimen to a constant mass at a temperature of 110 ± 5°C (230 ± 9°F), or determine the moisture content of a companion specimen according to T 329.

7.3. Enter into the ignition furnace, or manually record, the asphalt binder correction factor for the specific mix to be tested, as determined in the Annex.

7.4. Determine and record the mass of the specimen basket assembly to the nearest 0.1 g.

7.5. Prepare the specimen as described in Section 6. Place the specimen basket(s) in the catch pan. Evenly distribute the specimen in the basket(s), taking care to keep the material away from the edges of the basket. Use a spatula or trowel to level the specimen.

7.6. Determine and record the total mass of the specimen and specimen basket assembly at room temperature to the nearest 0.1 g. Calculate and record the initial mass of the specimen, $M_i$ (total mass minus the mass of the specimen basket assembly).

7.7. Input the initial mass of the specimen, $M_i$, in whole grams into the ignition furnace controller. Verify that the correct mass has been entered.

7.8. Open the chamber door and place the specimen basket assembly in the furnace, carefully positioning the specimen basket assembly so it is not in contact with the furnace walls. Close the chamber door and verify that the specimen mass (including the basket assembly) displayed on the furnace scale equals the total mass recorded in Section 7.6 within ±5 g. Differences greater than 5 g or failure of the furnace scale to stabilize may indicate that the specimen basket assembly is contacting the furnace wall.

**Note 3**—Due to the extreme heat of the furnace, the operator should wear safety equipment—high-temperature gloves, face shield, and fire-retardant shop coat—when opening the door to load or unload the specimen.

7.9. Initiate the test by pressing the start/stop button. This operation will lock the specimen chamber and start the combustion blower.

**Note 4**—The furnace temperature will drop below the set point when the door is opened but will recover with the door closed and when ignition occurs. Specimen ignition typically increases the temperature well above the set point, depending on the specimen size and asphalt binder content.
7.10. Allow the test to continue until the stable light and audible stable indicator indicate the test is complete (the change in mass does not exceed 0.01 percent for 3 consecutive min). Press the start/stop button. This operation will unlock the specimen chamber and cause the printer to print out the test results.

**Note 5**—An ending mass loss percentage of 0.02 may be substituted when the aggregate exhibits an excessive amount of loss during ignition testing. The precision and bias statement was developed using 0.01 percent. Both precision and accuracy may be adversely affected by using 0.02 percent.

7.11. Open the chamber door, remove the specimen basket assembly, and place it on a cooling plate or block. Place the protective cage over the specimen basket assembly, and allow it to cool to room temperature (approximately 30 min).

7.12. Determine and record the total mass of the specimen and specimen basket assembly after ignition to the nearest 0.1 g. Calculate and record the final mass of the specimen, \( M_f \) (total mass minus the mass of the specimen basket assembly).

7.13. Use the corrected asphalt binder content (percent) from the printed ticket. If this value is not corrected, subtract the asphalt binder correction factor. If a moisture content has been determined per T 329, subtract the percent moisture from the asphalt binder content on the printed ticket, and report the resultant value as the corrected asphalt binder content \( P_b \).

**Note 6**—Asphalt binder content can also be calculated using Equation 1 from Method B (Section 8.16).

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**TEST METHOD B—EXTERNAL BALANCE**

8. TEST PROCEDURES

8.1. Preheat the ignition furnace to 538 ± 5°C (1000 ± 9°F) or the temperature determined by the correction factor process in the Annex.

8.2. Oven dry the asphalt mixture specimen to a constant mass at a temperature of 110 ± 5°C (230 ± 9°F), or determine the moisture content of a companion specimen according to T 329.

8.3. Record the asphalt binder correction factor for the specific mix to be tested, as determined by the correction factor process in the Annex.

8.4. Determine and record the mass of the specimen basket assembly to the nearest 0.1 g.

8.5. Prepare the specimen as described in Section 6. Place the specimen baskets in the catch pan. Evenly distribute the specimen in the basket(s), taking care to keep the material away from the edges of the basket. Use a spatula or trowel to level the specimen.

8.6. Determine and record the total mass of the specimen basket assembly at room temperature to the nearest 0.1 g. Calculate and record the initial mass of the specimen, \( M_i \) (total mass minus the mass of the specimen basket assembly).

8.7. Open the chamber door and place the specimen basket assembly in the furnace. Burn the asphalt mixture specimen in the furnace for at least 45 min.
**Note 7**—The appropriate time for the initial burn of an asphalt mixture specimen is dependent on the specimen size. For large specimens, the time could be significantly longer than 45 min. See the Manufacturer’s Instruction Manual for guidelines.

8.8. Open the chamber door, remove the specimen basket assembly, and place it on a cooling plate or block. Place the protective cage over the specimen basket assembly, and allow it to cool to room temperature (approximately 30 min).

8.9. Determine and record the total mass of the specimen and specimen basket assembly after cooling to the nearest 0.1 g.

8.10. Place the specimen and specimen basket assembly back into the furnace.

8.11. Burn the specimen for at least 15 min after the furnace reaches the set point temperature.

8.12. Open the chamber door, remove the specimen and specimen basket assembly, and place it on a cooling plate or block. Place the protective cage over the specimen basket assembly, and allow it to cool to approximately room temperature (approximately 30 min).

8.13. Weigh and record the total mass of the specimen and specimen basket assembly after cooling to the nearest 0.1 g.

8.14. Repeat Sections 8.10 through 8.13 until the change in measured mass of the specimen after ignition does not exceed 0.01 percent of the initial specimen mass, $M_i$.

**Note 8**—An ending mass loss percentage of 0.02 may be substituted when the aggregate exhibits an excessive amount of loss during ignition testing. The precision and bias statement was developed using 0.01 percent. Both precision and accuracy may be adversely affected by using 0.02 percent. After the time required to obtain the specified mass loss has been established for each mixture, repeated mass determinations may not be necessary.

8.15. Calculate and record the final mass of the specimen, $M$ (total mass minus the mass of the specimen basket assembly).

8.16. Calculate the asphalt binder content of the specimen as follows:

$$P_b, \% = \left[ \frac{(M_i - M_f)}{M_i} \times 100 \right] - C_F - MC \tag{1}$$

where:

- $P_b$ = the measured (corrected) asphalt binder content, percent;
- $M_i$ = the total mass of the asphalt mixture specimen prior to ignition, g;
- $M_f$ = the total mass of aggregate remaining after the ignition, g;
- $C_F$ = the correction factor, percent by mass of asphalt mixture specimen; and
- $MC$ = the moisture content of the companion asphalt mixture specimen, percent, as determined by T 329. (If the specimen was oven dried prior to initiating the procedure, $MC = 0.$)

9. **GRADATION**

9.1. Allow the contents of the specimen baskets to cool to room temperature prior to performing the gradation analysis. Empty the contents of the baskets into a flat pan, being careful to capture all material. Use a small wire sieve brush to ensure that any residual fines are removed from the baskets and catch pan.
9.2. Perform the gradation analysis according to T 30.

10. REPORT

10.1. The report shall include the following:

10.1.1. Test method (A or B);

10.1.2. Corrected asphalt binder content;

10.1.3. Correction factor;

10.1.4. Temperature compensation factor (if applicable);

10.1.5. Specimen mass;

10.1.6. Moisture content (if determined, per T 329); and

10.1.7. Test temperature.

Note 9—If Method A is performed, attach the original printed ticket to the report.

11. PRECISION AND BIAS

11.1. Precision—Criteria for judging the acceptability of ignition burn results for asphalt binder content obtained by Method A or Method B are given in Table 2.

11.1.1. Single-Operator Precision—The figures in Column 2 of Table 2 are the standard deviations that have been found to be appropriate for the conditions of test described in Column 1. Two results obtained in the same laboratory, by the same operator using the same equipment, in the shortest practical period of time, should not be considered suspect unless the difference in the two results exceeds the values given in Table 2, Column 3.

11.1.2. Multilaboratory Precision—The figures in Column 2 of Table 2 are the standard deviations that have been found to be appropriate for the conditions of test described in Column 1. Two results submitted by two different operators testing the same material in different laboratories shall not be considered suspect unless the difference in the two results exceeds the values given in Table 2, Column 3.

Table 2—Precision Estimates

<table>
<thead>
<tr>
<th>Condition</th>
<th>Standard Deviation (1s)</th>
<th>Acceptable Range of Two Test Results (d2s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-operator precision</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asphalt binder content (%)</td>
<td>0.069</td>
<td>0.196</td>
</tr>
<tr>
<td>Multilaboratory precision</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asphalt binder content (%)</td>
<td>0.117</td>
<td>0.330</td>
</tr>
</tbody>
</table>

Note 10—The precision estimates given in Table 2 are based on the analysis of test results from three pairs of AMRL proficiency samples. The data analyzed consisted of results from 353 to
461 laboratories for each of the three pairs of samples. The analysis included two binder grades: PG 52-34 and PG 64-22. Average results for asphalt binder content ranged from 4.049 to 5.098 percent. The details of this analysis are in NCHRP Final Report, NCHRP Project No. 9-26, Phase 3.

Note 11—The precision estimates are based on four aggregate types, four replicates, and twelve laboratories participating with no laboratory results deleted as outlying observations. All four aggregates were tested in surface mixes and had relatively low absorption values.

11.2. Bias—Any biases inherent to the ignition oven process used for Test Methods A and B, when testing for asphalt binder content and aggregate gradation, are accounted for by the determination and application of appropriate correction factors.

12. KEYWORDS

12.1. Aggregate; asphalt binder; asphalt binder content; asphalt mixture; convection; correction factor; direct infrared irradiation; external balance; gradation; ignition; ignition furnace; internal balance.

ANNEX A—CORRECTION FACTORS

(Mandatory Information)

A1. ASPHALT BINDER AND AGGREGATE

A1.1. Asphalt binder content results may be affected by the type of aggregate in the mixture and the ignition furnace. Therefore, asphalt binder and aggregate correction factors must be established by testing a set of correction specimens for each job mix formula (JMF) mix design. Correction factor(s) must be determined before any acceptance testing is completed and repeated each time a change in the mix ingredients or design occurs. Any changes greater than 5 percent in stockpiled aggregate proportions should require a new correction factor. Historical data or scientific studies may be used to determine the correction factor(s) in lieu of using this testing procedure if the testing agency provides reference to the studies/data.

A1.2. Asphalt Binder Correction Factor—Certain aggregate types may result in unusually high correction factors (greater than 1.0 percent). Such mixes should be corrected and tested at a lower temperature, as described below. Each ignition furnace will have its own unique asphalt binder correction factor determined in the location where testing will be performed.

A1.3. Aggregate Correction Factor—Due to potential aggregate breakdown during the ignition process, an aggregate correction factor will be determined for each ignition furnace in the location where testing will be performed when the following conditions occur: aggregates that have a proven history of excessive breakdown or aggregates from an unknown source.

A2. CORRECTION FACTOR PROCEDURE

A2.1. Obtain samples of aggregate in accordance with R 90. Reduce the samples to testing size as needed according to R 76.

A2.2. Obtain samples of asphalt binder in accordance with R 66.

Note A1—Include other additives that may be required by the JMF.
A2.3. Prepare an initial, or “butter” mix at the design asphalt binder content. Mix and discard the butter mix prior to preparing any of the correction specimens to ensure an accurate asphalt binder content.

A2.4. Prepare two correction specimens at the JMF design asphalt binder content and gradation. Aggregate used for correction specimens shall be sampled from the material designated for use in production. An additional “blank” (aggregate only) specimen shall be batched at the JMF gradation. Determine an aggregate gradation in accordance with T 30 on the “blank” specimen.

A2.5. Place the freshly mixed specimens directly into the specimen basket assembly. If specimens are allowed to cool prior to placement in the specimen basket assembly, the specimens must be dried to constant mass at a temperature of 110 ± 5°C (230 ± 9°F). Do not preheat the specimen basket assembly.

A2.6. Test the specimens in accordance with Method A or Method B of the procedure.

A2.7. Once both of the correction specimens have been burned, determine the asphalt binder content for each specimen by calculation or from the printed oven tickets, if available.

A2.8. If the difference between the asphalt binder contents of the two specimens exceeds 0.15 percent, repeat Section A2.3 through A2.7 with two more specimens and, from the four results, discard the high and low result. Determine the correction factor from the two original or remaining results as appropriate. Calculate the difference between the actual and measured asphalt binder contents for each specimen. The asphalt binder correction factor, \( CF \), is the average of the differences expressed as a percentage by mass of the asphalt mixture.

A2.8.1. If the asphalt binder correction factor exceeds 1.0 percent, the test temperature should be lowered to 482 ± 5°C (900 ± 9°F) for a convection-type furnace. If there is no improvement in the correction factor, it is permissible to use the higher temperature.

Note A2 — The temperature for determining the asphalt binder content of asphalt mixture specimens by this procedure shall be the same temperature determined for the correction specimens.

A2.8.2. For the direct IR irradiation-type furnaces, the Default burn profile should be used for most materials. The operator may select burn-profile Option 1 or Option 2 to optimize the burn cycle. Option 1 is designed for aggregate that requires a large asphalt binder correction factor (greater than 1 percent)—typically very soft aggregate (such as dolomite). Option 2 is designed for samples that may not burn completely using the Default burn profile. The burn profile for testing asphalt mixture samples shall be the same burn profile selected for correction samples.

A2.9. Perform a gradation analysis on the residual aggregate in accordance with T 30, if required. The results will be utilized in developing an aggregate correction factor and should be calculated and reported to the nearest 0.1 percent.

A2.9.1. From the gradation results, subtract the percent passing each sieve for each specimen from the percent passing each sieve of the “blank” specimen gradation results from Section A2.4.

A2.9.2. Determine the average difference for the two values. If the difference for any single sieve exceeds the allowable difference for that sieve as listed in Table A2.1, then aggregate gradation correction factors (equal to the resultant average differences) for all sieves shall be applied to all acceptance gradation test results determined by T 30, prior to final rounding and reporting. If the 0.075-mm (No. 200) sieve is the only sieve outside the limits in Table A2.1, apply the aggregate correction factor to only the 0.075-mm (No. 200) sieve.
<table>
<thead>
<tr>
<th>Sieve</th>
<th>Allowable Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sizes larger than or equal to 2.36 mm (No. 8)</td>
<td>±5.0 percent</td>
</tr>
<tr>
<td>Sizes larger than 0.075 mm (No. 200) and smaller than 2.36 mm (No. 8)</td>
<td>±3.0 percent</td>
</tr>
<tr>
<td>Sizes 0.075 mm (No. 200) and smaller</td>
<td>±0.5 percent</td>
</tr>
</tbody>
</table>
Standard Method of Test for

Viscosity Determination
of Asphalt Binder Using
Rotational Viscometer

AASHTO Designation: T 316-19
Technical Subcommittee: 2b, Liquid Asphalt
Release: Group 3 (July)
1. SCOPE

1.1. This test method outlines the procedure for measuring the viscosity of asphalt binders at elevated temperature from 60 to over 200°C using a Rotational Viscometer apparatus as specified by M 320 and R 29.

1.2. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the application of regulatory limitations prior to use.

2. REFERENCED DOCUMENTS

2.1. AASHTO Standards:
   - M 320, Performance-Graded Asphalt Binder
   - R 29, Grading or Verifying the Performance Grade (PG) of an Asphalt Binder
   - R 66, Sampling Asphalt Materials

2.2. ASTM Standards:
   - C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
   - E1, Standard Specification for ASTM Liquid-in-Glass Thermometers

3. TERMINOLOGY

3.1. Definition:

3.1.1. viscosity—the ratio between the applied shear stress and the rate of shear is called the coefficient of viscosity. This coefficient is a measure of the resistance to flow of the liquid. It is commonly called the viscosity. The SI unit of viscosity is the Pascal second (Pa·s).

4. SUMMARY OF METHOD

4.1. This test method can be used to measure the viscosity of asphalt at application temperatures. The torque required to maintain a constant rotational speed of a cylindrical spindle while submerged in
an asphalt binder sample at a constant temperature is used to measure the relative resistance to rotation. The torque and speed are used to determine the viscosity of the binder in Pascal seconds.

5. SIGNIFICANCE AND USE

5.1. This test method can be used to measure the apparent viscosity of asphalt binder at application temperatures.

5.2. The measured viscosity at elevated temperatures can be used to determine whether the asphalt binder can be handled and pumped at the refinery, terminal, or hot mix plant facility. Measured viscosity from this procedure can be used to develop temperature viscosity charts for estimating mixing and compaction temperatures for use in asphalt mixture design.

6. APPARATUS

6.1. Oven—An oven capable of maintaining any desired temperature setting from room temperature to 260°C to within ±3°C.

6.2. Thermometers—Thermometers having a range from 60 to over 200°C and readable to 0.2°C.

6.3. Balance—A balance with a capacity of 2000 g readable to 0.1 g for determining the mass of asphalt binder.

6.4. Cylindrical Spindles of various sizes for measurement of asphalt binders of different viscosities.

6.5. Rotational Viscometer capable of measuring the torque required to rotate the selected spindle at a selected constant speed while submerged in asphalt binder at constant desired test temperature and should display the viscosity in Pascal seconds automatically.

6.6. Temperature Controller—A proportional temperature controller capable of maintaining the specimen temperatures ±1.0°C for test temperatures ranging from 60 to 165°C or greater.

7. MATERIALS

7.1. Solvent (such as mineral spirits or Varsol™) or a degreasing spray cleaner formulated for cleaning the sample holder, spindles, and accessories.

8. HAZARDS

8.1. Use standard laboratory safety procedures required for handling the hot asphalt binder and required safety procedures when cleaning with solvents or degreasers.

9. PREPARATION OF APPARATUS

9.1. The rotational viscometer must be leveled to function properly. A bubble-type level is normally located on top of the viscometer and is adjusted by using leveling screws located on the base. If the torque controller and thermal chamber are separate units, both should be leveled in accordance with the device manufacturer’s instructions.
10. CALIBRATION AND STANDARDIZATION

10.1. The accuracy of the rotary transducer is checked using a reference fluid (Newtonian fluid) of known viscosity at various temperatures. The reference fluid shall be certified to be Newtonian in behavior over the full range of expected test temperatures and shear rates. The viscosity measured should be within ±2 percent or the rotary transducer requires recalibration.

10.2. The accuracy of the temperature reading of the temperature controller is checked by placing an asphalt binder sample in the testing chamber and equilibrating to a given temperature. The indicated temperature shall be verified by using a NIST-traceable measuring device as defined by ASTM E1.

11. PREPARATION OF SAMPLES AND TEST SPECIMENS

11.1. Preparing Test Samples—Unaged asphalt and modified asphalt binders are obtained according to R 66.

11.1.1. Anneal the asphalt binder from which the specimen is obtained by heating until sufficiently fluid to pour. Annealing prior to testing removes reversible molecular associations (steric hardening) that may occur during normal storage at ambient temperature.

Note 1—Minimum pouring temperature that produces a consistency equivalent to that of SAE 10W30 motor oil (readily pours but not overly fluid) at room temperature is recommended. The specific temperature will depend on the grade of binder and its prior aging history, if any. Temperatures less than 135°C are desirable; however, temperatures above 135°C may be required for some modified asphalt binders or heavily aged binders.

12. PROCEDURE

12.1. Read and understand the information in the rotational viscometer manufacturer’s operating manual before proceeding.

12.2. Turn on the rotational viscometer and proportional temperature controller unit.

12.3. Preheat the sample holder with the sample chamber and the selected cylindrical spindle according to the manufacturer’s recommendation.

12.4. Set the proportional temperature controller to the desired test temperature.

12.5. Heat the required amount of asphalt binder as recommended by the manufacturer for testing according to Section 11.1.1.

12.6. When the proportional temperature controller reads the desired test temperature, remove the sample holder, and add the required amount of asphalt binder into the sample chamber.

12.7. Insert the sample chamber into the proportional temperature controller unit.

12.8. Insert a preheated spindle and attach it to the viscometer using the necessary coupling. Gently lower the spindle into the asphalt binder, so that the binder covers the upper conical portion of the spindle. This procedure may vary based on the manufacturer’s recommendations.

12.9. Bring the asphalt binder sample to the desired test temperature within approximately 30 min. Set the viscometer speed at 20 rpm and set the display to read the viscosity in Pascal seconds (Pa·s). This operation may be performed manually or by using a software program. The viscometer speed...
may be set higher than 20 rpm if it is expected that the observed torque will be out of range at 20 rpm.

12.10. Allow the asphalt binder sample to equilibrate at the desired test temperature for a minimum of 10 min. Begin the spindle rotation during the 10-min temperature equilibration period. Allow the readings to stabilize before recording any viscosity measurements. If the observed torque is out of range for the selected spindle and speed, change the spindle or speed based on the manufacturer’s recommendations for the anticipated viscosity. If a different spindle is used, restart the test with a new asphalt binder sample.

12.11. Start the test after the asphalt binder sample has reached the specified temperature and equilibrated and the viscosity readings have stabilized, as required in Sections 12.9 and 12.10.

12.12. Measure the viscosity at 1-min intervals for a total of 3 min.

12.13. Follow the procedure in Sections 12.1 to 12.12 for other temperatures.

13. **CALCULATION OF RESULTS**

13.1. The viscosity is reported as the average of three readings. If the digital output of the rotational viscometer viscosity is in units of centipoise (cP), the following factor is used to convert to Pascal-seconds:

\[
10 \text{ P} = 1 \text{ Pa} \cdot \text{s} \quad (1)
\]

\[
1 \text{ cP} = 1 \text{ mPa} \cdot \text{s} \quad (2)
\]

Multiply viscosity in centipoise by 0.001 to obtain the viscosity in Pa \cdot s.

14. **REPORT**

14.1. *Report the following information:*

14.1.1. The date and time of the test;

14.1.2. The test temperature to the nearest 1°C;

14.1.3. The speed in rpm;

14.1.4. The size of the spindle used;

14.1.5. The torque in percent; and

14.1.6. The average viscosity in Pa \cdot s.

15. **PRECISION AND BIAS**

15.1. *Precision*—Criteria for judging the acceptability of viscosity results obtained by this method are given in Table 1.

15.1.1. *Single-Operator Precision (Repeatability)*—The figures in Column 2 of Table 1 are the coefficients of variation that have been found to be appropriate for the conditions of test described in Column 1. Two results obtained in the same laboratory, by the same operator using the same equipment, in the shortest practical period of time, should not be considered suspect unless the
difference in the two results, expressed as a percent of their mean, exceeds the values given in Table 1, Column 3.

15.1.2. Multilaboratory Precision (Reproducibility)—The figures in Column 2 of Table 1 are the coefficients of variation that have been found to be appropriate for the conditions of test described in Column 1. Two results submitted by two different operators testing the same material in different laboratories shall not be considered suspect unless the difference in the two results, expressed as a percent of their mean, exceeds the values given in Table 1, Column 3.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Coefficient of Variation (1s%)</th>
<th>Acceptable Range of Two Test Results (d2s%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-operator precision:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average viscosity (Pa·s)</td>
<td>1.0</td>
<td>2.7</td>
</tr>
<tr>
<td>Multilaboratory precision:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average viscosity (Pa·s)</td>
<td>3.7</td>
<td>10.5</td>
</tr>
</tbody>
</table>

Note 2—The precision estimates given in Table 1 are based on the analysis of test results from ten pairs of AASHTO re:source proficiency samples. The data analyzed consisted of results from 225 to 276 laboratories for each of the ten pairs of samples. The analysis included seven binder grades: PG 58-28, PG 58-28 (modified), PG 64-22, PG 70-22, PG 70-28 (modified), PG 76-22 (modified), and PG 82-22 (modified). Unmodified binder average viscosity results ranged from 0.037 Pa·s to 0.657 Pa·s. The modified binder average viscosity results ranged from 0.662 Pa·s to 1.787 Pa·s. The methods used for this analysis are in the final report for NCHRP Project No. 9-26, Phase 3.

Note 3—As an example, two tests conducted on the same material yield viscosity results of 0.500 Pa·s and 0.510 Pa·s, respectively. The average of these two measurements is 0.505 Pa·s. The acceptable range of results is then 2.7 percent of 0.505 Pa·s or 0.014 Pa·s. As the difference between 0.500 Pa·s and 0.510 Pa·s is less than 0.014 Pa·s, the results are within the acceptable range.

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

16. KeyWords

16.1. Asphalt binder; viscosity.

1 Formerly AASHTO Provisional Standard TP 48. First published as a full standard in 2002.
Standard Method of Test for

Hamburg Wheel-Track Testing of Compacted Asphalt Mixtures

AASHTO Designation: T 324-19

Technical Subcommittee: 2c, Asphalt–Aggregate Mixtures

Release: Group 3 (July)
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1. SCOPE

1.1. This test method describes a procedure for testing the rutting and moisture-susceptibility of asphalt mixture pavement samples in the Hamburg Wheel-Tracking Device.

1.2. The method describes the testing of a submerged, compacted asphalt mixture in a reciprocating rolling-wheel device. This test provides information about the rate of permanent deformation from a moving, concentrated load. A laboratory compactor has been designed to prepare slab specimens. Also, the Superpave Gyratory Compactor (SGC) has been designed to compact specimens in the laboratory. Alternatively, field cores having a diameter of 150 mm (6 in.), 250 mm (10 in.), or 300 mm (12 in.), or saw-cut slab specimens may be tested.

1.3. The test method is used to determine the premature failure susceptibility of asphalt mixture due to weakness in the aggregate structure, inadequate binder stiffness, or moisture damage. This test method measures the rut depth and number of passes to failure.

1.4. This test method measures the potential for moisture damage effects because the specimens are submerged in temperature-controlled water during loading.

1.5. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns 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:

- R 30, Mixture Conditioning of Hot Mix Asphalt (HMA)
- T 166, Bulk Specific Gravity ($G_{mb}$) of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens
- T 168, Sampling Bituminous Paving Mixtures
- T 209, Theoretical Maximum Specific Gravity ($G_{mm}$) and Density of Hot Mix Asphalt (HMA)
- T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
- T 312, Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor
2.2. **ASTM Standards:**
- D6027, Standard Test Method for Calibrating Linear Displacement Transducers for Geotechnical Purposes, Method A
- D8079, Standard Practice for Preparation of Compacted Slab Asphalt Mix Samples Using a Segmented Rolling Compactor

2.3. **NCHRP Study:**

3. **SIGNIFICANCE AND USE**

3.1. This test measures the rutting and moisture susceptibility of an asphalt mixture specimen.

4. **SUMMARY OF METHOD**

4.1. A laboratory-compacted specimen of asphalt mixture, a saw-cut slab specimen, or a core taken from a compacted pavement is repetitively loaded using a reciprocating steel wheel. The specimen is submerged in a temperature-controlled water bath at a temperature specified by the agency. The deformation of the specimen, caused by the wheel loading, is measured.

4.2. The impression is plotted as a function of the number of wheel passes. An abrupt increase in the rate of deformation may coincide with stripping of the asphalt binder from the aggregate in the asphalt mixture specimen.

5. **APPARATUS**

5.1. **Hamburg Wheel-Tracking Device**—An electrically powered machine capable of moving a 203.2 ± 2.0-mm (8 ± 0.08-in.) diameter, 47 ± 0.5-mm (1.85 ± 0.02-in.) wide steel wheel over the center (x and y axes) of the test specimen. The load on the wheel is 703 ± 4.5 N (158.0 ± 1.0 lb). The wheel reciprocates over the specimen, with the position varying sinusoidally over time. A maximum level of deviation from a perfectly sinusoidal wave is defined through the root-mean square error (RMSE), which is calculated as follows:

\[
RMSE = \sqrt{\frac{\sum e_i^2}{n}} \quad (1)
\]

where:
- \(e_i\) = deviation from a pure sinusoidal curve, and
- \(n\) = number of data points.

The maximum allowable deviation from a sinusoidal wave through the entire track length is set at an RMSE of 2.54 mm (0.1 in.) unless otherwise specified by the agency. The wheel makes 52 ± 2 passes across the specimen per minute. The maximum speed of the wheel, reached at the midpoint of the specimen, is 0.305 ± 0.02 m/s (1 ± 0.066 ft/s).

**Note 1**—Follow the NCHRP Report or available devices in the market meeting the relevant requirements as proposed in the NCHRP Report to verify the sinusoidal wave requirement of the Hamburg wheel tracking device.
5.2. **Temperature Control System**—A water bath capable of controlling the temperature within ±1.0°C (1.8°F) over a range of 25 to 70°C (77 to 158°F) with a mechanical circulating system stabilizing the temperature within the specimen tank.

5.2.1. **Impression Measurement System**—A linear displacement transducer (LDT) device capable of measuring the depth of the impression (rut) of the wheel to within 0.15 mm (0.006 in.), over a minimum range of 0 to 20 mm (0 to 0.8 in.). The system shall measure the depth of the impression at a minimum at the following locations along the track length: −114 (−4.5), −91 (−3.6), −69 (−2.7), −46 (−1.8), −23 (−0.9), 0 (0), +23 (+0.9), +46 (+1.8), +69 (+2.7), +91 (+3.6), and +114 (+4.5) mm (in.) with zero being the midpoint of the track unless otherwise specified by the agency. The midpoint of the track shall be marked by the manufacturer. The system measures the rut depth, without stopping the wheel, at least every 20 passes. Rut depth is expressed as a function of the wheel passes. The device will also disengage if the average LDT displacement (read from the micro-control unit, not the screen) is 40.90 mm (1.6 in.) or greater for an individual specimen. Note that the screen readout subtracts the initial LDT reading from the total displacement.

**Note 2**—The locations of the deformation readings should be verified experimentally using the aluminum apparatus presented in Appendix X2. The maximum allowable RMSE at the 11 pre-set locations after taking into account the effect of curvature of the aluminum apparatus discussed in the NCHRP Report is 1.27 mm (0.05 in).

5.3. **Wheel Pass Counter**—A non-contacting solenoid that counts each wheel pass over the specimen. The signal from this counter is coupled to the wheel impression measurement, allowing for the rut depth to be expressed as a function of the wheel passes.

5.4. **Slab Specimen Mounting System**—A stainless steel tray that is mounted rigidly to the machine. The mounting system must restrict shifting of the specimen to within 0.5 mm (0.02 in.) during testing and must suspend the specimen to provide a minimum of 20 mm (0.8 in.) of free circulating water on all sides of the mounting system.

5.5. **Cylindrical Specimen Mounting System**—An assembly consisting of two high-density polyethylene (HDPE) molds or plaster of Paris, in accordance with Section 8 to secure the specimen (as shown in Figures 1 and 2), placed on a stainless steel tray that is mounted rigidly to the machine. This mounting system must restrict shifting of the specimen to within 0.5 mm (0.02 in.) during testing and must suspend the specimen to provide a minimum of 20 mm (0.8 in.) of free circulating water on all sides of the mounting system.
5.6. **Linear Kneading Compactor**—A hydraulic-powered unit that uses a series of vertically aligned steel plates to compact molded asphalt mixtures into flat, rectangular slabs of predetermined thickness and density.
5.7. **Balance**—Of 12 000-g capacity, accurate to 0.1 g.

5.8. **Ovens**—For heating aggregate and asphalt binders.

5.9. **Superpave Gyratory Compactor (SGC)**—And molds conforming to T 312.

5.10. Bowls, spoon, spatula, etc.

6. **SPECIMEN PREPARATION**

6.1. **Number of Test Specimens**—Prepare two test specimens for each test, either slab specimens or cylinders.

6.2. **Laboratory-Produced Asphalt Mixture**:

6.2.1. Batch mixture proportions in accordance with the desired job mix formula.

6.2.2. Use the mixing temperature at which the asphalt binder achieves a viscosity of 170 ± 20 cSt. For modified asphalt binders, use the mixing temperature recommended by the binder manufacturer.

6.2.3. Dry-mix the aggregates and mineral admixture (if used) first, then add the correct percentage of asphalt binder. Mix the materials to coat all aggregates thoroughly. (Wet-mix the aggregates if using a lime slurry or other wet material.)

6.2.4. Condition test samples at the appropriate compaction temperature in accordance with the short-term conditioning procedure for mechanical properties in R 30.

6.2.5. Use the compaction temperature at which the asphalt binder achieves a viscosity of 280 ± 30 cSt. For modified asphalt binders, use the compaction temperature recommended by the binder manufacturer.

6.2.6. **Laboratory Compaction of Specimens**—Compact either slab specimens or SGC cylindrical specimens.

6.2.6.1. **Compacting Slab Specimens**—Heat molds and tools to compaction temperature. Compact slab specimens 320 mm (12.5 in.) long and 260 mm (10.25 in.) wide using a Linear Kneading Compactor (or equivalent such as a compactor meeting ASTM D 8079). Specimen thickness must be at least twice the nominal maximum aggregate size, generally yielding a specimen 38 to 100 mm (1.5 to 4 in.) thick. Allow compacted slab specimens to cool at normal room temperature on a clean, flat surface until cool to the touch.

6.2.6.2. **Compacting SGC Cylindrical Specimens**—Compact two 150-mm (6-in.) diameter specimens in accordance with T 312. Specimen thickness must be at least twice the nominal maximum aggregate size, generally yielding a specimen 38 to 100 mm (1.5 to 4 in.) thick. Allow compacted specimens to cool at normal room temperature on a clean, flat surface until cool to the touch.

6.3. **Field-Produced Asphalt Mixture—Loose Mix**:

6.3.1. Obtain a sample of asphalt mixture in accordance with T 168.

6.3.2. **Laboratory Compaction of Specimens**—Compact either slab specimens or SGC cylindrical specimens in accordance with Section 6.2.6.

6.4. **Field-Produced Asphalt Mixture—Field Compacted (Core/Slab Specimen)**:
6.4.1. Cutting Field Cores or Field Slab Specimens—Field cores or field slab specimens consist of wet saw-cut compacted specimens taken from asphalt mixture pavements. Cut field cores 300 mm (12 in.), 250 mm (10 in.), or 150 mm (6 in.) in diameter. Cut field slab specimens approximately 260 mm (10.25 in.) wide by 320 mm (12.5 in.) long. Use a slab specimen thickness of 38 to 100 mm (1.5 to 4 in.). The height of a field core or field slab specimen is typically 38 mm (1.5 in.), but may be adjusted to fit the specimen mounting system by wet saw-cutting. Cut field cores in accordance with Section 6.4.2.

Note 3—Take care to load the sample so it is level to the surface of the mold. Trim the sample if it is too tall, or use shims if it is too short (supporting with plaster if needed). Calibrate the down pressure from the wheel to be 703±4.5 N (158.0± 1.0 lb) at the center, level to the top of the mold position. Even a small change in elevation will change the down pressure significantly.

6.4.2. Cutting SGC Cylindrical Specimens and Field Cores—Cut specimens after they have cooled to room temperature using a wet or dry saw. Saw the specimens along equal secant lines (or chords) such that when joined together in the molds, there is no space between the cut edges. The amount of material sawed from the SGC cylindrical specimens may vary to achieve a gap width no greater than 7.5 mm (0.3 in.) between the molds.

Note 4—To cut specimens consistently may require the use of a jig.

7. DETERMINING AIR VOID CONTENT

7.1. Determine the bulk specific gravity of the specimens in accordance with T 166.

7.2. Determine the maximum specific gravity of the mixture in accordance with T 209.

7.3. Determine the air void content of the specimens in accordance with T 269. The recommended target air void content is 7.0 ± 0.5 percent for laboratory-compacted SGC cylindrical specimens and 7.0 ± 1.0 percent for laboratory-compacted slab specimens. Field specimens may be tested at the air void content at which they are obtained.

8. PROCEDURE

8.1. Slab and Large Field Core Specimen Mounting—Use plaster of Paris to rigidly mount the 300 mm (12 in.), 250 mm (10 in.), or slab specimens in the mounting trays. Mix the plaster at approximately a 1:1 ratio of plaster to water. Pour the plaster to a height equal to that of the specimen to fill the air space between the specimen and the sides of the mounting tray. The slab specimen will be in direct contact with the mounting tray; however, plaster may flow underneath the specimen. If the thickness of the Slab or Large Field Core Specimen is the same as the height of the mounting tray, the plaster underneath the specimen must not exceed 2 mm (0.08 in.). If the thickness of the Slab or Large Field Core Specimen is less than the height of the mounting tray, plaster and/or shims from aluminum, HDPE, or other suitable material shall be used underneath the specimen as necessary to bring the top of the specimen level with the top of the mounting tray and to prevent any movement of the specimen in the mounting tray during testing. Allow the plaster at least 1 h to set. If using other mounting material, it should be able to withstand 890 N (200 lb) of load without cracking.

8.2. SGC Cylindrical and Field Core Specimen Mounting—Rigidly mount the 150-mm [5.91-in.] or 152-mm [6-in.] diameter samples in the mounting tray using HDPE molds meeting the dimensions outlined in Figure 2 or use plaster of Paris. For HDPE molds, place the molds in the mounting tray and insert the cut specimens in the molds. Shim the molds in the mounting tray as necessary. Secure the molds into the mounting tray. If plaster of Paris is used, pour the plaster to a height equal to that of the specimen to fill the air space between the specimen and the sides of the mounting tray. The specimen will be in direct contact with the mounting tray; however, plaster
may flow underneath the specimen. For SGC Cylindrical Specimens the plaster underneath the specimen must not exceed 2 mm (0.08 in.) in thickness. For Field Core Specimens plaster and/or shims from aluminum, HDPE, or other suitable material shall be used underneath the specimen as necessary to bring the top of the specimen level with the top of the HDPE molds and to prevent any movement of the specimen in the molds during testing. Allow the plaster at least 1 h to set.

**Note 5**—Cores drilled with a 152-mm [6-in.] drill bit may not fit in the 150-mm [5.91-in.] HDPE mold and may require further trimming and mounting in plaster of Paris.

8.3. Place the mounting tray(s) with the test specimens into the device. Adjust the height of the specimen tray as recommended by the manufacturer, and secure by hand-tightening the bolts.

8.4. Turn the testing device and all components on.

8.5. Start the software used to communicate with the testing device.

8.6. Enter the pertinent project information and testing configuration requirements.

8.6.1. Select the test temperature based on the applicable specifications.

8.6.2. Select the maximum allowable rut depth based on the applicable specifications.

8.6.3. Select the maximum number of passes based on the applicable specifications.

8.6.4. Enter a start delay of 45 min to precondition the test specimens. The temperature of the specimens in the mounting tray will be the test temperature selected in Section 8.6.1 on completion of this preconditioning period.

8.7. Proceed to Section 8.8 to operate the testing device in “Auto” mode. Proceed to Section 8.9 to operate the testing device in “Manual” mode.

**Note 6**—Perform the test in “Auto” mode for testing devices manufactured in the United States later than 1998, where software will automatically open and close the valves to fill and drain the water bath. Perform the test in “Manual” mode for devices made available to the United States prior to 1998.

8.8. Performing the Test in Auto Mode:

8.8.1. Adjust the height of the LDT in accordance with the manufacturer’s recommendations.

**Note 7**—The LDT for each steel wheel is automatically zeroed at the start of the test. The software will display a zero at the start of the test.

8.8.2. If using cylindrical specimens, lower the wheels onto the edge of the test specimens such that a majority of the wheel is in contact with the HDPE molds in the mounting tray. If using slabs, lower the wheels onto the specimen no more than 5 min prior to the beginning of the test. In either case, the sample must not be submerged longer than 60 ± 5 min prior to starting the test. This includes the conditioning time.

8.8.3. Start the test by selecting the “Start” button of the testing device software.

**Note 8**—The start delay time or preconditioning time will start after the water heats to the test temperature selected in Section 8.6.1.

8.8.4. The wheel-tracking device will stop when 20,000 passes have occurred, when some other predetermined number of passes has occurred, or when the test has achieved the maximum impression depth established in Section 8.6.2. The testing device software automatically saves the test data file.
8.8.5. Raise the wheel(s) and remove the specimen mounting tray(s) and rutted specimens.

8.8.6. Proceed to Section 8.10.

8.9. Performing the Test in Manual Mode:

8.9.1. Close the drain valve(s) and fill the water bath of the wheel-tracking device with water until the float device(s) raises to a horizontal position. 
Note 9—Adjust the amount of hot and cold water if necessary, as the water temperature may vary.

8.9.2. Precondition the test specimens in the water bath for 45 min after the water has reached the selected test temperature. Do not place the sample in the conditioning bath more than 60 ± 5 min prior to beginning the test. This includes the preconditioning time.

8.9.3. Lower the wheels onto the specimens after the test specimens have preconditioned at the selected test temperature for 45 min. For machines that start automatically after the selected preconditioning time, it is allowable to lower the wheels before the preconditioning cycle. The wheel must not be in contact with the specimen for more than 5 min prior to starting the wheel.

8.9.4. Ensure the micro-control unit’s LDT reads between 10 and 18 mm (0.4 and 0.7 in.). Adjust the LDT height to obtain this reading. Loosen the two screws on the LDT mount and slide the LDT up or down to the desired height. Tighten the screws.

8.9.5. Start the test.

8.9.6. The wheel-tracking device will stop when 20,000 passes have occurred, when some other predetermined number of passes has occurred, or when the test has achieved the maximum impression depth established in Section 8.6.2.

8.9.7. Open the valve(s) beneath the tanks and drain the water bath. Raise the wheel(s) and remove the specimen mounting tray(s) and rutted specimens.

8.10. Clean the water bath, heating coils, wheels, and temperature probe with water and scouring pads or per the manufacturer’s recommendations. Use a wet-dry vacuum to remove particles that have settled to the bottom of the baths. Clean the filter element and spacers after every test or per the manufacturer’s recommendations. Do not use solvents to clean the water bath.

8.11. Turn the wheels after each test, so the same section of the wheel surface is not in contact with the test specimen from test to test. This rotation will provide for even wear over the entire wheel. The test should operate with a smooth movement across the test specimen.

9. CALCULATIONS

9.1. For the purposes of this method, a “test” is defined as:

a) Two 320-mm (12.5-in.) long by 260-mm (10.25-in.) wide slab specimens, two 250-mm (10-in.) core specimens, or two 300-mm (12-in.) core specimens representing similar material run in the Hamburg Wheel-Tracking Device simultaneously; or

b) Four 150-mm (6-in.) diameter specimens grouped in pairs (1 and 1a) representing similar material run in the Hamburg Wheel-Tracking Device simultaneously.

The test results will be reported as the average value of both specimens (a) or both pairs of specimens (b).
9.2. The maximum rut depth shall be calculated based on the average rut depth for the five middle deformation locations (i.e., located at –46 (–1.8), –23 (–0.9), 0, +23 (+0.9), and +46 (+1.8) mm (in.)) or other suitable method as specified by the agency. Plot the rut depth versus number of passes for each test for each deformation location. Figure 3 shows a typical plot of the output produced by the Hamburg Wheel-Tracking Device. From this plot, obtain the following values:

- slope and intercept of the first steady-state portion of the curve, and
- slope and intercept of the second steady-state portion of the curve.

Figure 3—Hamburg Curve with Test Parameters

9.3. Calculate the following test parameters, all expressed in “Passes.”

\[
\text{stripping inflection point (SIP)} = \frac{\text{intercept (second portion)} - \text{intercept (first portion)}}{\text{slope (first portion)} - \text{slope (second portion)}}
\]

(1)

where:

- Failure rut depth is the specified maximum allowable rut depth for the test.

**Note 10**—The specifying agency may choose to define a “test” as an individual slab or core specimen or as a pair of specimens as defined in Section 9.1.

10. **REPORT**

10.1. The report may include the following parameters:

10.1.1. Asphalt mixture production (field or lab);

10.1.2. Compaction method (slab or SGC cylindrical specimen);

10.1.3. Number of passes at maximum impression;
10.1.4. Maximum impression;
10.1.5. Test temperature;
10.1.6. Specimen(s) air voids;
10.1.7. Type and amount of anti-stripping additive used;
10.1.8. Creep slope;
10.1.9. Strip slope; and
10.1.10. Stripping inflection point.

11. PRECISION AND BIAS

11.1. Work is underway to develop precision and bias statements for this standard.

12. KEYWORDS

12.1. Compacted asphalt mixture; moisture-susceptibility; rutting; wheel-track testing.

ANNEX A—EVALUATING HAMBURG WHEEL DIMENSIONS

(Mandatory Information)

A1. SCOPE

A1.1. This Annex covers the evaluation of the steel wheel as a check for compliance with the requirements outlined in Section 5.1. Measurements of the wheel’s diameter and width, as well as visual inspection of critical surface conditions, are included. Minimum frequency of this evaluation is 12 months.

A2. APPARATUS

A2.1. Measurement Instrument (Calipers or Micrometer)—With appropriate range and a minimum resolution of 0.1 mm (0.004 in.). The measurement instrument shall be standardized annually.

A3. PROCEDURE FOR MEASURING THE DIAMETER OF THE HAMBURG WHEEL

A3.1. Perform a visual inspection of the wheel: The wheel shall be free of residue and deep gouges. Identify any wear that may be visible on the wheel.

A3.2. Determine the maximum diameter of the wheel by measuring it at several locations. Place a removable mark at the maximum diameter position. Record the maximum diameter to the nearest 0.1 mm (0.004 in.).

A3.3. Measure the diameter at a 90-degree orientation to the maximum diameter. Record this diameter to the nearest 0.1 mm (0.004 in.).
A3.4. Each individual diameter measurement shall be compared to the specified range and given a pass/fail rating. If any of the individual measurements are assigned a “fail” rating, the wheel is considered to be out of conformance and shall not be used.

A4. PROCEDURE FOR MEASURING THE WIDTH OF THE HAMBURG WHEEL

A4.1. *Perform a visual inspection of the wheel loading surface:* The edge shall be free of residue and deep gouges. Identify any wear that may be visible on the edge of the wheel.

A4.2. Determine the maximum width of the wheel by measuring it at several locations. Place a removable mark at this position. Record the maximum width to the nearest 0.1 mm (0.004 in.).

A4.3. Measure the width at a 90-degree, 180-degree, and 270-degree orientation to the maximum width. Record each width to the nearest 0.1 mm (0.004 in.).

A4.4. Each individual width measurement shall be compared to the specified range and given a pass/fail rating. If any of the individual measurements is assigned a “fail” rating, the wheel is considered to be out of conformance and shall not be used.

A5. INSPECTION REPORT

A5.1. *Record and report the following information:*

A5.2. Name of evaluator;

A5.3. Date;

A5.4. Equipment owner;

A5.5. Location of evaluation;

A5.6. Hamburg Wheel-Tracker model;

A5.7. Diameter measurements of the wheel to the nearest 0.1 mm (0.004 in.);

A5.8. Width of the loading surface of the wheel to the nearest 0.1 mm (0.004 in.).

APPENDIXES

(Nonmandatory Information)

X1. MAINTENANCE

X1.1. Grease all of the grease fittings with fresh grease every 20 tests (not to exceed 2 months) per the manufacturer’s recommendations.
X2. CALIBRATION/EQUIPMENT VERIFICATION

X2.1. Verify the water bath temperature is within ±1.0°C (1.8°F) of the temperature readout from the testing device or software every 6 months. Measure the water bath temperature at four locations per the manufacturer’s recommendations. Average the four measurements and report this as the water bath verification temperature.

X2.2. Verify the LDT calibration in accordance with ASTM D6027 or per the manufacturer’s recommendations.

X2.3. Verify the load from the wheel loading assembly at the level of the initial height of the test per the manufacturer’s recommendations to be 703 ± 4.5 N (158.0 ± 1.0 lb). A calibrated load cell, accurate to 0.4 N (0.1 lb) is sufficient for this check. Align the center of the load cell with the middle of the wheel width as well as the center axis of the wheel.

X2.4. Verify that the wheel is reciprocating on the test sample at 52 ± 2 passes per minute.

X2.5. Verify that rut measurements are obtained at the 11 pre-set locations defined in Section 5.2.1. The aluminum apparatus presented in Figure X1.1 should be used.

X2.6. The wheel position varying sinusoidally over time shall be verified to have a maximum RMSE of 2.54 mm (0.1 in) unless otherwise specified by the agency from a perfectly sinusoidal wave.

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<th>Offset (mm)</th>
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Figure X1.1—Details of the metal specimen
Standard Method of Test for

Moisture Content of Asphalt Mixtures by Oven Method

Technical Subcommittee: 2c, Asphalt–Aggregate Mixtures
Release: Group 3 (July)
1. SCOPE

1.1. This method is intended for the determination of moisture content of asphalt mixtures by drying in an oven.

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

1.3. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns 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
- R 47, Reducing Samples of Asphalt Mixtures to Testing Size
- T 168, Sampling Bituminous Paving Mixtures

3. SUMMARY OF TEST METHOD

3.1. A test specimen of asphalt mixture is dried in a forced-air, ventilated, or convection oven to constant mass.

4. APPARATUS

4.1. Balance or Scale—2-kg (4.4-lb) capacity, readable to at least 0.1 g and conforming to the requirements of M 231.

4.2. Forced-Air, Ventilated, or Convection Oven—capable of maintaining the temperature surrounding the sample at 163 ± 14°C (325 ± 25°F).
4.3. *Sample Container*—The container in which the sample is dried shall be of sufficient size to contain the sample without danger of spilling and to allow the sample to be evenly distributed in a manner that will allow completion of the test in an expeditious manner.

4.4. *Thermometers*—Readable to the nearest 2°C (4°F), for determining temperatures of asphalt mixtures. Armored-glass, dial type, or digital thermometers with metal stems are recommended.

5. **SAMPLE**

5.1. A sample of asphalt mixture shall be obtained in accordance with T 168.

5.2. The sample shall be reduced in size in accordance with R 47. The size of the test sample shall be a minimum of 1000 g.

6. **PROCEDURE**

6.1. Determine and record the mass of the sample container including any material used to line the sample container to the nearest 0.1 g.

   **Note 1**—When using paper or other absorptive material to line the sample container, ensure it is dry before determining the initial mass of the sample container.

6.2. Place the test sample in the sample container. Determine and record the temperature of the test sample. To facilitate drying, evenly distribute the test sample in the sample container.

6.3. Determine and record the total mass of the sample container and moist test sample to the nearest 0.1 g.

6.4. Preheat the oven to drying temperature. The drying temperature shall fall within the job mix formula mixing temperature range. If a mixing temperature range is not supplied, a temperature of 163 ± 14°C (325 ± 25°F) will be used.

   **Note 2**—For repeatability between operators and/or laboratories, the difference between drying temperatures for samples should not exceed 9°C (15°F).

6.5. Calculate the mass of the initial, moist test sample by subtracting the mass of the sample container determined in Section 6.1 from the total mass of the sample container and moist test sample determined in Section 6.3.

6.6. Dry the sample initially for 90 ± 5 min and determine its mass. Then continue to dry the sample to constant mass, checking at 30 ± 5-min intervals until further drying does not alter the mass by more than 0.05 percent.

   **Note 3**—The moisture content of test samples and the number of test samples in the oven will affect the rate of drying at any given time. Placing wet test samples in the oven with nearly dry test samples could affect the drying process.

6.7. Cool the sample container and test sample to approximately the same temperature as determined in Section 6.2.

6.8. Determine and record the total mass of the sample container and dry the test sample to the nearest 0.1 g.

   **Note 4**—Do not attempt to remove the test sample from the sample container for the purposes of determining the dry mass of the test sample.
6.9. Calculate the mass of the final, dry test sample by subtracting the mass of the sample container determined in Section 6.1 from the total mass of the sample container and dry test sample determined in Section 6.8.

7. **CALCULATIONS**

7.1. Calculate moisture content as follows:

\[
\text{moisture content, } \% = \frac{M_i - M_f}{M_f} \times 100 \tag{1}
\]

where:

- \(M_i\) = mass of the initial, moist test sample, g; and
- \(M_f\) = mass of the final, dry test sample, g.

Example:

\[
M_i = 1134.9 \text{ g} \\
M_f = 1127.3 \text{ g}
\]

\[
\text{moisture content, } \% = \frac{1134.9 \text{ g} - 1127.3 \text{ g}}{1127.3 \text{ g}} \times 100 = 0.67\%
\]

7.2. Calculate the percent change in mass, as described in Section 6.6, as follows:

\[
\% \text{ change} = \left( \frac{M_p - M_n}{M_p} \right) \times 100 \tag{2}
\]

where:

- \(M_p\) = previous mass measurement; and
- \(M_n\) = new mass measurement.

8. **REPORT**

8.1. Report the moisture content to the nearest 0.01 percent.

9. **KEYWORDS**

9.1. Hot mix asphalt; moisture content; oven-drying.
Standard Method of Test for

Bulk Specific Gravity ($G_{mb}$) and Density of Compacted Asphalt Mixtures Using Automatic Vacuum Sealing Method

AASHTO Designation: T 331-13 (2017)$^1$

Technical Section: 2c, Asphalt–Aggregate Mixtures

Release: Group 3 (August)

ASTM Designation: D6752/D6752M-11
Standard Method of Test for

Bulk Specific Gravity \( (G_{mb}) \) and Density of Compacted Asphalt Mixtures Using Automatic Vacuum Sealing Method

AASHTO Designation: T 331-13 (2017)¹

Technical Section: 2c, Asphalt–Aggregate Mixtures

Release: Group 3 (August)

ASTM Designation: D6752/D6752M-11

1. SCOPE

1.1. This method covers the determination of bulk specific gravity \( (G_{mb}) \) of specimens of compacted asphalt mixtures.

1.2. This method should be used with samples that contain open or interconnecting voids and/or absorb more than 2.0 percent of water by volume, as determined by T 166. An agency may specify this method as an alternative to T 275.

1.3. The bulk specific gravity \( (G_{mb}) \) of the compacted asphalt mixture may be used in calculating the unit mass of the mixture.

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

1.5. *This standard may involve hazardous materials, operations, and equipment. 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
- R 79, Vacuum Drying Compacted Asphalt Specimens
- T 166, Bulk Specific Gravity \( (G_{mb}) \) of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens
- T 275, Bulk Specific Gravity \( (G_{mb}) \) of Compacted Asphalt Mixtures Using Paraffin-Coated Specimens
- T 312, Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor
2.2. **ASTM Standard:**
- E1, Standard Specification for ASTM Liquid-in-Glass Thermometers

2.3. **Other Document:**
- FHWA-IF-02-044, NCAT Report No. 02-11, *Bulk Specific Gravity Round-Robin Using the CoreLok™ Vacuum Sealing Device*

3. **TERMINOLOGY**

3.1. **Definitions:**

3.1.1. *bulk specific gravity (of solids)—*the ratio of the mass in air of a unit volume of a permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the mass in air of equal density of an equal volume of gas-free distilled water at a stated temperature.

The form of the expression shall be:

Bulk specific gravity at \( x/y \)°C

where:

\( x \) = temperature of the material; and
\( y \) = temperature of the water.

3.1.2. *constant mass—*shall be defined as the mass at which further drying does not alter the mass by more than 0.05 percent when the mass is determined at 2-h intervals.

4. **TEST SPECIMENS**

4.1. Test specimens may be either laboratory-compacted asphalt mixtures or sampled from asphalt pavements. The mixtures may be surface or wearing course, binder or leveling course, or hot mix base.

4.2. *Size of Specimens—*Specimens shall conform to the requirements of T 166.

4.3. Specimens shall be taken from pavements with a core drill, diamond or carborundum saw, or by other suitable means.

4.4. Care shall be taken to avoid distortion, bending, or cracking of specimens during and after the removal from the pavement or mold. Specimens shall be stored in a safe, cool place.

4.5. Specimens shall be free from foreign materials such as seal coat, tack coat, foundation material, soil, paper, or foil.

4.6. If desired, specimens may be separated from other pavement layers by sawing or other suitable means. Care should be exercised to ensure sawing does not damage specimens. Jagged edges or sharp aggregates may puncture the plastic bag. Specimen ends or planar edges may require sawing if the bag does not conform to the specimen in a uniform manner.

5. **APPARATUS**

5.1. *Bag Cutter—*A knife, scissors, or other types of clipping devices may be used to quickly open bags.
5.2. **Oven**—The oven shall be capable of maintaining the appropriate temperature for drying specimens to a constant mass.

5.3. **Weighing Device**—The weighing device shall have sufficient capacity, be readable to 0.1 percent of the sample mass or better, and conform to the requirements of M 231. The weighing device shall be equipped with a suitable suspension apparatus and holder to determine the mass of the specimen while suspended from the center of the scale pan of the weighing device.

5.4. **Plastic Bags**—The two most commonly used sizes of bags are designated as small and large size bags. The small bags shall have a minimum opening of 235 mm (9.25 in.) and a maximum opening of 260 mm (10.25 in.) with a mass of less than 35 g. The large bags shall have a minimum opening of 375 mm (14.75 in.) and a maximum opening of 394 mm (15.5 in.) with a mass of 35 g or more. The bags shall be made of a plastic material that will not adhere to asphalt film and shall be puncture-resistant, capable of withstanding sample temperatures of up to 70°C (158°F), impermeable to water, and contain no air channels for evacuation of air from the bag. The bags shall have a minimum thickness of 0.100 mm (0.004 in.) and a maximum thickness of 0.152 mm (0.006 in.). The manufacturer shall provide the bag correction factor (apparent specific gravity) of the bags (usually located in the operator’s manual). See the manufacturer’s recommendations to ensure proper handling of bags.

5.5. **Specimen Sliding Plates**—Level and smooth-sided planar filler plates shall be inserted into the chamber to keep the samples of various heights level with the seal bar while being sealed. The plates shall be removable and of the appropriate dimensions to easily fit into the vacuum chamber. A smooth-sided specimen supporting plate shall easily slide on top of the smooth-sided plates. The opposite side of the smooth-sided specimen supporting plate shall have a cushioning membrane to help prevent tears in the plastic bag. The plate shall be large enough to fully support the specimen but small enough to allow movement during the sealing process.

5.6. **Suspension Apparatus**—The wire suspending the container shall be of the smallest practical size to minimize any possible effects of a variable immersed length. The suspension apparatus shall be constructed to enable the container to be immersed to a depth sufficient to cover it and the test sample during weighing.

5.7. **Thermometer**—ASTM 17C (17F) as provided in ASTM E1, having a range of 19 to 27°C (66 to 80°F), graduated and conforming to ASTM E1. An electronic temperature measuring device, such as a resistance thermometer or thermocouple, may be used.

5.8. **Vacuum Chamber**—The pump shall be capable of evacuating the sealed and enclosed chamber to 5 mmHg in 60 s at sea level. The chamber shall be large enough to seal samples of 150-by-350-by-150 mm (6-by-14-by-6 in.). A sealing bar of sufficient length to fully seal small and large size bags shall be located inside the chamber. The heat setting shall be set according to the manufacturer’s recommendations and the bag composition. The device shall automatically seal the plastic bag and exhaust air back into the chamber in a controlled manner to ensure proper conformance of the plastic bag to the specimen. The air exhaust and vacuum operation time should be calibrated to bring the chamber to atmospheric pressure in 80 to 120 s after completion of the vacuum operation. The vacuum system should be provided with a latch to control chamber door opening.

5.9. **Vacuum Gauge (Standardized)**—The standardized vacuum gauge shall be capable of being placed inside the automatic vacuum sealing device to verify vacuum performance and seal integrity. The gauge shall have a minimum range of 10 to 0 mmHg (10 to 0 torr) and shall be readable to 1 mmHg (1 torr) increments, as a minimum.

5.10. **Water Bath**—For immersing the specimen in water while suspended under the weighing device, equipped with an overflow outlet for maintaining a constant water level and thermostatically
controlled so as to maintain the bath at 25 ± 1°C (77 ± 1.8°F). A heater and circulator may be attached. The circulator shall not be in use while recording sample masses. It is important that the water bath be of sufficient size to ensure sufficient space for the sample and the plastic bag suspension. A water bath with suggested minimum dimensions (length by width by depth) of 610-by-460-by-460 mm (24-by-18-by-18 in.) or a large cylindrical container has been found to work well for this test method. (See Note 1.)

**Note 1**—If a cushioned holder is used inside the water bath, it should not have sharp edges. Cushioned holders with sharp edges have been found to puncture the plastic bags. A clip may be attached to the container to hold the plastic bags underwater and to keep edges of the plastic bags from touching the edges of the water bath. Water baths at eye level may help prevent tears in bags and assist in ease of use.

### 6. PROCEDURE

6.1. **Initial Mass of Specimen in Air**—Dry the specimen to a constant mass at a temperature of 52 ± 3°C (125 ± 5°F), or vacuum-dry the specimen according to R 79. Samples saturated with water shall initially be dried overnight and then the mass determined at 2-h drying intervals. Recently compacted laboratory samples that have not been exposed to moisture do not require drying. Cool the specimen to room temperature at 25 ± 5°C (77 ± 9°F), and record the initial dry mass as \( A \). It is important that the sample contain less than 5 g of water before it is exposed to vacuum. At high vacuum, water will evaporate, potentially causing the bag around the sample to loosen due to trapped gas, thus resulting in a higher volume determination and a lower bulk specific gravity result.

**Note 2**—Bulk specific gravity \( (G_{sb}) \) determined by this method may be lower, and air voids higher, than the results obtained by T 166. The differences may be more pronounced for coarse and absorptive mixtures. Users of this test method are cautioned to evaluate any alteration in asphalt content or aggregate gradation for mix designs with a positive performance history. If this procedure will be used for control or assurance testing, users are cautioned to follow this procedure during the laboratory mix design.

**Note 3**—Laboratory-compacted specimens of 3000 to 6000 g may be considered at room temperature equilibrium after 2 h of cooling under a fan. The cooling time may be reduced for smaller specimens or if verified to have no significant differences in properties from those cooled to room temperature equilibrium.

**Note 4**—Some steps may be performed in conjunction with T 166.

6.2. **Sealing the Specimen**—Select an appropriately sized bag for the specimen. Specimens of 100 mm (4 in.) and 150 mm (6 in.) in diameter and up to 50 mm (2 in.) in thickness are usually tested with a small bag. Specimens of 150 mm (6 in.) in diameter by 50 mm (2 in.) or greater in thickness will usually be tested with a large bag.

6.2.1. Set the heat-sealing bar temperature according to the bag manufacturer’s recommendations.

6.2.2. Inspect the bag for holes and irregularities, then record the bag mass. Place the bag inside the vacuum chamber on top of the specimen sliding plate.

6.2.3. Insert the specimen into the bag with the smoothest plane of the specimen on the bottom. This operation may be done inside the chamber while holding the bag open with one hand over the sliding plate and gently inserting the specimen with the other hand. There should be about 25 mm (1 in.) of slack between the presealed bag end and the specimen.

6.2.4. If needed, filler plates should be added or removed prior to inserting the specimen. Grab the unsealed end of the bag on each side, and gently pull and center it over the seal bar, overlapping the bag at least 25 mm (1 in.).
6.2.5. Ensure that there are no wrinkles in the bag along the seal bar just prior to closing the lid.

6.2.6. Close the lid, and engage the lid-retaining latch. The vacuum pump light will illuminate “red,” and the vacuum gauge on the exterior of the chamber will become active, or a digital reading will show the vacuum state. It is normal for the bag to expand or “puff up” during this process.

6.2.7. Once sealed, the “de-vac” valve will open, and air will enter the chamber, causing atmospheric pressure to collapse the bag around the specimen.

6.2.8. Disengage the lid-retaining latch, and carefully remove the sealed specimen from the chamber. Gently pull on the bag at any areas that appear loose. Loose areas indicate a poor seal and the process must then be restarted at Section 6.1 with a new bag and a new initial mass.

6.3. Sealed Specimen Mass—Calculate the mass of the sealed specimen in air by summing the masses recorded in Sections 6.1 and 6.2.2. Designate this mass as \( B \).

6.4. Mass of Sealed Specimen in Water—Quickly weigh the sealed specimen in a water bath at 25 ± 1°C (77 ± 1.8°F). Fully submerge the specimen and bag to ensure no trapped air bubbles exist under the specimen. Ensure that the bag is completely underwater and that it is not touching the edges of the water bath. Designate this mass as \( E \).

Note 5—The time between the lid opening after sealing and the time to placement of the specimen into the water bath should not exceed 1 min to reduce the potential for bag leaks.

6.5. Check—To ensure a tight seal in the bag, remove the sample from the water, and cut the bag open. Remove the sample from the bag, and determine its mass. Designate this mass as \( C \). Compare this mass with initial dry mass determined in Section 6.1 as \( A \). If \( A \) is more than 5 g from the mass of dry specimen \( C \), the results from this method may not be accurate. The check passes if less than 0.08 percent is lost or no more than 0.04 percent is gained. A loss indicates sample material loss, and a gain indicates a possible bag leakage problem. Remove the bag, and restart the process at Section 6.1 if this check fails.

6.6. If the specimen may be needed for referee testing, oven-dry the specimen as described in Method C of T 166 or vacuum-dry it according to R 79.

6.7. If the specimen will not be needed for referee testing, oven-dry the specimen as described in Method A of T 166, or vacuum-dry it according to R 79.

7. CALCULATION

7.1. Calculate the bulk specific gravity \( (G_{mb}) \) of the specimen as follows. Round and report the value to the nearest 0.001.

\[
G_{mb} = \frac{A}{\left[C + (B - A) - E - \frac{B - A}{F}\right]} \quad (I)
\]

where:
- \( G_{mb} \) = specimen bulk specific gravity;
- \( A \) = initial mass of the dried specimen in air, g;
- \( B \) = calculated mass of the dry, sealed specimen, g;
- \( C \) = final mass of the specimen after removal from the sealed bag, g;
- \( E \) = mass of the sealed specimen underwater, g; and
\[ F = \text{bag correction factor (apparent specific gravity) of the plastic sealing material at } 25^\circ\text{C (77°F), provided by the bag manufacturer.} \]

7.2. Calculate the density of the specimen as follows. Round and report the value to the nearest 1 kg/m³ (lb/ft³).

\[ \hat{\rho} = G_{mb} (\hat{a}) \]  

(2)

where:

- \( G_{mb} = \) bulk specific gravity of the specimen;
- \( \hat{\rho} = \) density of the specimen, kg/m³ or lb/ft³ (pcf); and
- \( \hat{a} = \) density of water at 25°C (77°F), (997.1 kg/m³, 0.9971 g/cm³, or 62.245 lb/ft³, pcf).

8. VERIFICATION

8.1. Vacuum System Verification:

8.1.1. The vacuum settings of the device shall be verified once every three months, after repairs, and after shipment or relocation, as a minimum.

8.1.2. Verification shall be performed with an absolute vacuum gauge capable of being placed inside the chamber and reading the vacuum setting of the sealing device.

8.1.3. Place the gauge inside the chamber and record the setting. The gauge should indicate a reading of 10 mmHg (10 torr) or less. The unit should not be used if the gauge reading is above 10 mmHg (10 torr).

8.2. Plastic Bag Verification:

8.2.1. The bag correction factor (apparent specific gravity) of the plastic bag provided by the bag manufacturer shall be verified periodically.

8.2.2. Compact an asphalt mixture specimen of 4.75-mm (No. 4) nominal-maximum aggregate size with a Marshall compactor or gyratory compactor (according to T 245 or T 312, respectively) to minimum dimensions of 100 mm (4 in.) in diameter by 60 mm (2.4 in.) thick. The sample should be compacted to produce air voids of 4.0 ± 1.0 percent. Alternatively, compact a fine-graded asphalt mixture specimen of 9.5-mm nominal-maximum aggregate size with a Marshall compactor or gyratory compactor (according to T 245 or T 312, respectively) to minimum dimensions of 150 mm (6 in.) in diameter by 100 mm (4 in.) thick. The sample should be compacted to produce air voids of 4.0 ± 1.0 percent.

8.2.3. Using three bags from the same size set of plastic bags and the compacted specimen from Section 8.2.2, follow Section 6 as appropriate; determine the bulk specific gravity (\( G_{mb} \)) of the compacted specimen for each individual bag.

8.2.4. Average the three bulk specific gravities (or densities) obtained with each bag.

8.2.5. Determine the bulk specific gravity (\( G_{mb} \)) of the same compacted specimen, by T 166.

8.2.6. The average bulk specific gravity (or density) calculated for the asphalt mixture specimen using the plastic bags shall be within ±0.020 g/cm³ (20 kg/m³) of the bulk specific gravity (or density) as determined by T 166 for the same asphalt mixture specimen. If the difference between T 166 and T 331 bulk specific gravities is outside of the required tolerance, dry the sample per the procedures in Section 6.1, and repeat the above verification test. Average the values for the first and second
verification tests, and ensure that the difference is less than or equal to 0.020 g/cm³. Contact the manufacturer if this verification test fails.

8.2.7. This section shall be repeated for each bag size.

9. **PRECISION**

9.1. Criteria for judging the acceptability of bulk specific gravity results obtained by this test method are given in Table 1.

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<th>Test and Type Index</th>
<th>Standard Deviation</th>
<th>Acceptable Range of Two Results</th>
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<tr>
<td>Single-operator precision</td>
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<tr>
<td>Multilaboratory precision</td>
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</table>

*Table 1—Acceptability of Bulk Specific Gravity (Gmb)*

The precision estimates were obtained from *Bulk Specific Gravity Round-Robin Using the CoreLok™ Vacuum Sealing Device* report. The FHWA pooled-fund study report number was FHWA-IF-02-044, NCAT Report No. 02-11.

9.2. The figures given in Column 2 are the standard deviations that have been found to be appropriate for the conditions of the test described in Column 1. The figures given in Column 3 are the limits that should not be exceeded by the difference between results of two properly conducted tests.

1 Similar, but not identical, to ASTM D6752/D6752M-11.
Standard Test Method for Effect of Moisture on Asphalt Concrete Paving Mixtures

This standard is issued under the fixed designation D4867/D4867M; 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 procedures for preparing and testing asphalt concrete specimens for the purpose of measuring the effect of water on the tensile strength of the paving mixture. This test method is applicable to dense mixtures such as those appearing in the Table for Composition of Bituminous Paving Mixtures in Specification D3515. This test method can be used to evaluate the effect of moisture with or without antistripping additives including liquids and pulverulent solids such as hydrated lime or portland cement.

1.2 The values stated in either SI units or inch-pound units in parentheses shall be regarded separately as standard. The values in each system may not be exact equivalents; therefore, each system must be used independently of the other, without combining values in any way.

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

D979 Practice for Sampling Bituminous Paving Mixtures
D1074 Test Method for Compressive Strength of Bituminous Mixtures
D1561 Practice for Preparation of Bituminous Mixture Test Specimens by Means of California Kneading Compactor
D2041 Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
D2726 Test Method for Bulk Specific Gravity and Density of Non-Absorbent Compacted Bituminous Mixtures
D3203 Test Method for Percent Air Voids in Compacted Bituminous Paving Mixtures

D3387 Test Method for Compaction and Shear Properties of Bituminous Mixtures by Means of the U.S. Corps of Engineers Gyratory Testing Machine (GTM)
D3496 Practice for Preparation of Bituminous Mixture Specimens for Dynamic Modulus Testing
D3515 Specification for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures
D3549 Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens
D3665 Practice for Random Sampling of Construction Materials
D4013 Practice for Preparation of Test Specimens of Bituminous Mixtures by Means of Gyratory Shear Compactor
D4123 Test Method for Indirect Tension Test for Resilient Modulus of Bituminous Mixtures
D6926 Practice for Preparation of Bituminous Specimens Using Marshall Apparatus

3. Summary of Test Method

3.1 Potential for Moisture Damage—The degree of susceptibility to moisture damage is determined by preparing a set of laboratory-compacted specimens conforming to the job-mix formula without an additive. The specimens are compacted to a void content corresponding to void levels expected in the field, usually in the 6 to 8 % range. The set is divided into two subsets of approximately equal void content. One subset is maintained dry while the other subset is partially saturated with water and moisture conditioned. The tensile strength of each subset is determined by the tensile splitting test. The potential for moisture damage is indicated by the ratio of the tensile strength of the wet subset to that of the dry subset.

3.2 Additive Effect—The effect of an antistripping additive is determined on a set of specimens containing an additive prepared and tested as described in 3.1. The effect of an additive dosage may be estimated by repeating the tests on sets with different additive dosages.

3.3 Plant-Produced Mixtures—The potential for moisture damage or the effectiveness of an additive in a plant-produced...
mixture is determined on specimens that are laboratory compacted to expected field-level void content, divided into wet and dry subsets, and evaluated as described in 3.2.

4. Significance and Use

4.1 This test method can be used to test asphalt concrete mixtures in conjunction with mixture design testing to determine the potential for moisture damage, to determine whether or not an antistripping additive is effective, and to determine what dosage of an additive is needed to maximize the effectiveness. This test method can also be used to test mixtures produced in plants to determine the effectiveness of additives under the conditions imposed in the field.

5. Apparatus

5.1 To prepare and compact the specimens use apparatus from any one of the following: Test Methods D1074, and D3387, Practice D3496, or Practices D1561, D4013, and D6926.

5.2 Vacuum Pump or Water Aspirator in accordance with Test Method D2041.

5.3 Manometer or Vacuum Gage in accordance with Test Method D2041.

5.4 Container, preferably Type F, of Test Method D2041.

5.5 Balance in accordance with Test Method D2726.

5.6 Water Baths Three:

5.6.1 One waterbath in accordance with Test Method D2726.

5.6.2 One bath capable of maintaining a temperature of 60 ± 1.0°C (140 ± 1.8°F) for 24 h, and

5.6.3 One bath capable of maintaining a temperature of 25 ± 1.0°C (77 ± 1.8°F).

5.7 Mechanical or Hydraulic Testing Machine capable of maintaining the required strain rate and measuring load with equal or better precision.

5.8 Loading Strips in accordance with Test Method D4123.

6. Preparation of Laboratory Test Specimens

6.1 Make at least six specimens for each test, three to be tested dry and three to be tested after partial saturation and moisture conditioning.

6.2 Use specimens 100 mm (4 in.) in diameter and 62.5 mm (2.5 in.) high, in general, but specimens of other dimensions may be used if desired. When using aggregate larger than 25 mm (1 in.), use specimens at least 150 mm (6 in.) in diameter.

NOTE 1—The user is cautioned that the specimen diameter has been determined to influence both the tensile strength and the tensile strength ratio. The tensile strength and the tensile strength ratio values may be different for 150-mm specimens compared to 100-mm specimens.

6.3 Prepare mixtures in batches large enough to make at least 3 specimens or, as an alternative, prepare a batch just large enough for 1 specimen. If theoretical maximum specific gravity is to be determined, use a batch large enough or prepare a separate batch to provide a specimen for this purpose.

6.4 When a liquid antistripping additive is used, heat a sufficient quantity of asphalt cement for one batch to 150 ± 6°C (300 ± 10°F) in a closed 1 L (1-qt) can in an oven. Add the required quantity of additive and immediately mix, for approximately 2 min, with a mechanical stirrer approximately 25 mm (1 in.) from the bottom of the container. Maintain the treated asphalt cement at 150 ± 6°C (300 ± 10°F) in the closed can until it is used. Discard the treated asphalt cement if not used the same day it is prepared, or if allowed to cool so that it requires reheating.

6.5 When using a pulverulent solid antistripping additive , use the addition procedure simulating the procedure expected in the field. Follow the procedure specified in either 6.5.1, 6.5.2, or 6.5.3.

6.5.1 When dry powder is added to dry aggregate, dry, batch, and heat the mineral aggregate to 150 ± 6°C (300 ± 10°F). Add the required quantity of additive to the aggregate, and thoroughly mix the entire mass until a uniform distribution of additive is achieved. Take care to minimize the loss of additive to the atmosphere in the form of dust. After mixing, maintain the treated aggregate at the required mixing temperature until it is used.

6.5.2 When dry powder is added to damp aggregate, batch the damp mineral aggregate, and adjust the moisture content of the combined aggregate to the expected field moisture level. Add the required quantity of additive to the damp aggregate, and thoroughly mix the entire mass until a uniform distribution of additive is achieved. Take care to minimize the loss of additive to the atmosphere in the form of dust. After mixing, dry the treated aggregate, heat to the required mixing temperature, and maintain at that temperature until it is used.

6.5.3 When powder slurry is used, add the required quantity of additive to water using the powder to water ratio expected in the field. Take care to minimize the loss of additive to the atmosphere in the form of dust. To prevent settling, continuously mix the resulting slurry until it is used. Batch the damp mineral aggregate, adjust the moisture content as required in 6.5.2, add the required quantity of slurry, and thoroughly mix the entire mass until a uniform distribution of slurry is achieved. After mixing, dry the treated aggregate, heat to the required mixing temperature, and maintain at that temperature until used.

6.6 Proportion, mix, and compact specimens in accordance with one of the following: Test Methods D1074, D3387, Practice D3496, Practices D1561, D4013, or D6926, and 6.6.1 and 6.6.2.

6.6.1 After mixing, stabilize the mixture temperature of each specimen at the required compaction temperature, in a closed container, in an oven for 1 to 2 h. If preparing a multi-specimen batch, split the batch into single-specimen quantities before placing into the oven.

6.6.2 Compact the specimens to 7 ± 1 % air voids, or a void level expected in the field at the time of construction. This void level can be obtained by adjusting the following: the static load in double-plunger compaction; the number of blows in a marshall hammer compaction; the foot pressure, number of
tamps, leveling load, or some combination in kneading compaction; or the number of revolutions in gyratory compaction. Determine the exact procedure by trial for each mixture.

6.6.3 Cool specimens in the mold to room temperature as rapidly as possible in a stream of moving air, extract from molds, then follow the procedure outlined in Section 8 within 24 h.

7. Preparation of Field Specimens

7.1 Select a truck to be sampled in accordance with Practice D3665.

7.2 Secure a sample from the truck at the plant in accordance with Practice D979.

7.3 Stabilize the mixture temperature to approximately the temperature found in the field when rolling begins. Maintain this temperature in a closed container, in an oven if necessary, for approximately the time lapse between mixing and the start of actual rolling.

7.4 Compact the specimens in accordance with 6.6.2, and cool and extract from the molds in accordance with 6.6.3.

7.5 If specimens are not to be compacted in the field laboratory, place the samples in a sealed container, transport to the laboratory, and reheat to the temperature required in 7.3. Proceed with the steps in 7.4.

NOTE 2—Specimens made from plant-produced mixtures in accordance with Section 7 may yield different results from specimens made from laboratory-produced mixtures of the same job mix made in accordance with Section 6.

8. Procedure

NOTE 3—A data sheet that is convenient for use with this procedure appears in Appendix X1.

8.1 Determine the theoretical maximum specific gravity in accordance with Test Method D2041.

8.2 Determine the specimen height in accordance with Test Method D3549.

8.3 Determine the bulk specific gravity in accordance with Test Method D2726, and express the volume of the specimen in cubic centimeters. The term \( B-C \) in Test Method D2726 is the volume of the specimen in cubic centimeters.

8.4 Calculate the percent air voids in accordance with Test Method D3203, and express the volume of air in cubic centimeters. The volume of air is the volume of the specimen in 8.3 multiplied by the percent air voids.

8.5 Sort the specimens into two subsets so that the average air voids of the two subsets are approximately equal. Store the subset to be tested dry at room temperature.

8.6 Partially saturate the subset to be moisture conditioned with distilled water at room temperature using a vacuum chamber. If it is difficult to reach the minimum degree of saturation required in 8.6.3, the water used to saturate may be heated up to 60°C (140°F).

8.6.1 Partially saturate, to the degree specified in 8.6.3, by applying a partial vacuum such as 70 kPa or 525 mm Hg (20 in. Hg) for a short time such as five min.

NOTE 4—Experiments with partial vacuum at room temperature indicate that the degree of saturation is very sensitive to the magnitude of the vacuum and practically independent of the duration. The level of vacuum needed appears to be different for different mixtures.

8.6.2 Determine the volume of the partially saturated specimen in accordance with Test Method D2726. Determine the volume of the absorbed water by subtracting the air-dry mass of the specimen in 8.3 from the saturated surface-dry mass of the partially saturated specimen.

8.6.3 Determine the degree of saturation by dividing the volume of the absorbed water in 8.6.2 by the volume of air voids in 8.4 and express the result as a percentage. If the volume of water is between 55 and 80 % of the volume of air, proceed to 8.7. If the volume of water is less than 55 %, repeat the procedure beginning with 8.6.1 using a slightly higher partial vacuum. If the volume of water is more than 80 %, the specimen has been damaged and is discarded.

NOTE 5—If the average air voids of the saturated subset is less than 6.5 %, a degree of saturation of at least 70 % is recommended.

8.7 Moisture condition the partially saturated specimens by soaking in distilled water at 60 ± 1.0°C (140 ± 1.8°F) for 24 h.

NOTE 6—If a freeze-thaw conditioning cycle is desired, the following procedure is suggested instead of the procedure in 8.7. Wrap each of the partially saturated specimens tightly with two layers of plastic film using masking tape to hold the wrapping if necessary. Place each wrapped specimen into a leak-proof plastic bag containing approximately 3 mL of distilled water, and seal the bag with a tie or tape. Place the wrapped and bagged specimens into an air bath freezer at −18 ± 2.0°C (−4 ± 3.6°F). After at least 15 h in the freezer, remove the specimens and immerse them in a water bath at 60 ± 1.0°C (140 ± 1.8°F) for 24 h. After 3 min of immersion, after specimen surface thaw occurs, remove the bag and wrapping from the specimens.

8.8 Adjust the temperature of the moisture-conditioned subset by soaking in a water bath for 1 h at 25 ± 1°C (77 ± 1.8°F).

8.9 Measure the height of the moisture-conditioned subset by Test Method D3549, and determine volume by Test Method D2726.

8.9.1 Determine the water absorption and the degree of saturation in accordance with 8.6.2 and 8.6.3. A degree of saturation exceeding 80 % is acceptable.

8.9.2 Determine the swell of the partially saturated specimens by dividing the change in specimen volumes in 8.6.2 and 8.3 by the specimen volume in 8.3. Determine the swell of moisture-conditioned specimens by dividing the change in the specimen volume in 8.9 and 8.3 by the specimen volume in 8.3.

8.10 Adjust the temperature of the dry subset by soaking in a water bath for 20 min at 25 ± 1.0°C (77 ± 1.8°F).

8.11 Determine the tensile strength at 25 ± 1.0°C (77 ± 1.8°F) of both subsets.

8.11.1 Place a specimen into the loading apparatus and position the loading strips so that they are parallel and centered on the vertical diametral plane. Apply a diametral load at 50 mm/min (2 in./min) until the maximum load is reached, and record the maximum load.

8.11.2 Continue loading until the specimen fractures. Break the specimen open and visually estimate and record the approximate degree of moisture damage, if any.
8.11.3 Inspect all surfaces, including the failed faces, for evidence of cracked or broken aggregate, that may influence test results, and record observations.

9. Calculation

9.1 Calculate the tensile strength as follows:

\[ S_t = 2000 \frac{P}{\pi tD} \text{ (kPa)} \]  

or

\[ S_t = 2\frac{P}{\pi tD} \text{ (psi)} \]  

where:

- \( S_t \) = tensile strength, kPa (psi)
- \( P \) = maximum load, N (lbf)
- \( t \) = specimen height immediately before tensile test, mm (in.), and
- \( D \) = specimen diameter, mm (in.).

9.2 Calculate the tensile strength ratio as follows:

\[ TSR = \left( \frac{S_{tm}}{S_{td}} \right) \times 100 \]  

where:

- \( TSR \) = tensile strength ratio, %
- \( S_{tm} \) = average tensile strength of the moisture-conditioned subset, kPa (psi), and
- \( S_{td} \) = average tensile strength of the dry subset, kPa (psi).

10. Report

10.1 Report the following information:

10.1.1 Number of specimens in each subset,
10.1.2 Average air voids of each subset,
10.1.3 Average degree of saturation after partial saturation and after moisture conditioning,
10.1.4 Average swell after partial saturation and after moisture conditioning,
10.1.5 Tensile strength of each specimen in each subset,
10.1.6 Tensile strength ratio,
10.1.7 Results of visually-estimated moisture damage observed when the specimen fractures, and
10.1.8 Results of observations of fractured or crushed aggregate.

Note 7—If the conditioning procedure described in Note 6 is used, that fact should be included in the report.

11. Precision and Bias

11.1 Precision—The standard deviations for use with this test method have been determined using laboratory-mixed specimens conditioned in accordance with 8.7. Neither plant-mixed material nor the conditioning in Note 6 has been studied. Nineteen laboratories participated in the precision study by testing five asphalt concrete mixtures, two of which contained a liquid antistripping additive.

11.1.1 Within-Laboratory Precision—The single-operator standard deviation of tensile strength for either dry or moisture-conditioned specimens has been found to be 55 kPa (8 psi). The \( \text{d}_2s \) limit for the maximum allowable difference in tensile strength between duplicate specimens of the same mixture tested by the same operator is 159 kPa (23 psi).

11.1.2 Between-Laboratory Precision—The multilaboratory standard deviation of the tensile-strength ratio has been found to be 8 %. The \( \text{d}_2s \) limit for the maximum allowable difference in tensile-strength ratio between results of tests performed on samples of the same mixture by two different laboratories is 23 %.

11.2 Bias—This test method has an undetermined bias because the value of a tensile-strength ratio can be defined only in terms of the test method.

12. Keywords

12.1 antistripping additives; asphalt concrete paving mixtures; moisture; tensile strength; water

APPENDIX

(Nonmandatory Information)

XI. MOISTURE DAMAGE LABORATORY DATA SHEET
<table>
<thead>
<tr>
<th>Project</th>
<th>Additive</th>
<th>Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Compaction Method**

<table>
<thead>
<tr>
<th>Effort</th>
<th>Date Tested</th>
<th>By</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample I.D.</th>
<th>Diameter, mm (in.)</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thickness, mm (in.)</td>
<td>t</td>
</tr>
<tr>
<td></td>
<td>Dry mass in air</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>SSD mass</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>Mass in water</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>Volume (B-C)</td>
<td>E</td>
</tr>
<tr>
<td></td>
<td>Bulk Sp. Gr. (A/E)</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td>Max Sp. Gr.</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td>% AirVoid (100(G-F)/G)</td>
<td>H</td>
</tr>
<tr>
<td></td>
<td>Volume AirVoid, HE/100</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>Load, N (lbf)</td>
<td>P</td>
</tr>
</tbody>
</table>

**Saturated min. @ kPa or mm Hg (in. Hg)**

<table>
<thead>
<tr>
<th>SSD Mass</th>
<th>Mass in water</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume (B-C)</td>
<td></td>
<td>E'</td>
</tr>
<tr>
<td>Vol Abs. water (B-A)</td>
<td></td>
<td>J</td>
</tr>
<tr>
<td>% Saturation (100J/I)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Swell (100(E-J)/E)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Conditioned 24 h in 140°F water**

| Thickness, mm (in.) | F |
| Mass in water       | C' |
| Volume (B'-C')      | E' |
| Vol Abs. Water (B'-A) | J' |
| % Saturation, (100J'/I) |   |
| % Swell, 100(E'-J')/E |   |
| Load, N (lbf)      | P |

**Dry Strength, 2000 P/πtD (2P/πtD)**

| wet Strength, 2000 P/πtD' (2P/πtD') | S_{sw} |
| TDR, 100S_{sw}/S_{td} |   |
| Visual Moisture Damage |   |
| Crack/Break Aggregate |   |

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Standard Practice for

Preparation of Asphalt Mixtures by Means of the Marshall Apparatus

AASHTO Designation: R 68-15 (2019)¹

Technical Subcommittee: 2d, Proportioning of Asphalt–Aggregate Mixtures

Release: Group 3 (July)
1. SCOPE

1.1. This standard practice describes procedures for the compaction of cylindrical specimens of asphalt mixtures using the Marshall compaction hammer. This practice is for use with mixtures containing asphalt binder or asphalt cutback and aggregate up to 25.4-mm (1-in.) maximum size.

2. REFERENCED DOCUMENTS

2.1. AASHTO Standards:

- M 231, Weighing Devices Used in the Testing of Materials
- R 30, Mixture Conditioning of Hot Mix Asphalt (HMA)
- R 97, Sampling Asphalt Mixtures
- T 166, Bulk Specific Gravity ($G_{mb}$) of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens
- T 275, Bulk Specific Gravity ($G_{mb}$) of Compacted Asphalt Mixtures Using Paraffin-Coated Specimens
- T 331, Bulk Specific Gravity ($G_{mb}$) and Density of Compacted Asphalt Mixtures Using Automatic Vacuum Sealing Method

3. APPARATUS

3.1. Specimen Mold Assembly—Mold cylinders 101.6 mm (4 in.) in diameter by 76.2 mm (3 in.) in height, base plates, and extension collars shall conform to the details shown in Figure 1. Three mold cylinders are recommended.
Figure 1—Specimen Mold Assembly

Table 1—Table of Equivalents for Figure 1

<table>
<thead>
<tr>
<th>Metric Equivalents, mm</th>
<th>U.S. Customary Units, in.</th>
<th>Metric Equivalents, mm</th>
<th>U.S. Customary Units, in.</th>
<th>Metric Equivalents, mm</th>
<th>U.S. Customary Units, in.</th>
<th>Metric Equivalents, mm</th>
<th>U.S. Customary Units, in.</th>
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<tr>
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<td>19.0</td>
<td>3/4</td>
<td>63.5</td>
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<td>22.2</td>
<td>7/8</td>
<td>69.8</td>
<td>2 7/8</td>
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<tr>
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<td>76.2</td>
<td>3</td>
<td>117.5</td>
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<tr>
<td>6.4</td>
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<td>7.1</td>
<td>9/32</td>
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<td>3 3/8 96/128</td>
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<td>101.47</td>
<td>3 995/128</td>
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<td>14.3</td>
<td>9/16</td>
<td>50.8</td>
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<td>101.6</td>
<td>4</td>
<td>193.7</td>
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<td>15.9</td>
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<td>57.2</td>
<td>2 1/4</td>
<td>101.73</td>
<td>4 005</td>
<td>685.8</td>
<td>27</td>
</tr>
</tbody>
</table>
3.2. Specimen Extractor—Steel, in the form of a disk with a diameter not less than 100 mm (3.95 in.) and 12.7 mm (1/2 in.) thick for extracting the compacted specimen from the specimen mold with the use of the mold collar. A suitable bar is required to transfer the load from the ring dynamometer adapter to the extension collar while extracting the specimen. A hydraulic jack or similar device may also be used provided specimens are not damaged during extraction.

3.3. Compaction Hammer:

3.3.1. Manual Hammer—The compaction hammer (Figure 2) shall have a flat, 98.4 ± 3.2 mm (37/8 ± 1/8 in.) circular tamping face and a 4536 ± 9 g (10 ± 0.02 lb) sliding weight (including a safety finger guard if so equipped) with a free fall of 457.2 ± 1.524 mm (18 ± 0.06 in.).

3.3.2. Automatic Hammer—An automatic hammer shall meet the requirements listed for manual hammers in Section 3.3.1. The automatic hammer consists of the mechanical compactor, an automatic counter, and a tapered-foot hammer assembly for rotating-mold models or a flat-foot hammer assembly for stationary mold models. To calibrate the automatic hammer to the manual hammer, compact six specimens: three specimens using the manual hammer and three specimens using the automatic hammer. Use the same number of blows for each specimen. After the specimens have cooled to room temperature, use T 166, T 275, or T 331 to determine the average bulk densities of the two sets of specimens. If the bulk densities of the two sets of specimens are within 2.0 percent of each other, then the results are comparable. If the results are not within 2.0 percent of each other, then the tests need to be repeated using more or fewer blows on the automatic hammer to achieve a comparable density.

Figure 2—Compaction Hammer (Manual)

3.4. Compaction Pedestal—The compaction pedestal shall consist of a 203.2-by-203.2-by-457.2-mm (8-by-8-by-18-in.) wooden post capped with a steel plate with minimum dimensions of 304.8-by-
3.5. Specimen Mold Holder—Mounted on the compaction pedestal so as to center the compaction mold over the center of the post. It shall hold the compaction mold, collar, and base plate securely in position during compaction of the specimen.

3.6. Ovens or Hot Plates—Ovens or hot plates shall be provided for heating aggregates, asphalt material, specimen molds, compaction hammers, and other equipment to the required mixing and molding temperatures. It is recommended that the heating units be thermostatically controlled so as to maintain the required temperature within 2.8°C (5°F). Suitable shields, baffle plates, or sand baths shall be used on the surfaces of the hot plates to minimize localized overheating.

3.7. Heating Device—A small hot plate with continuously variable heating rate, a sand bath, infrared lamp, or other suitable device shall be available for supplying sufficient heat under the mixing bowl to maintain the aggregate and asphalt material at the desired temperature during mixing. If a hot plate is used, a wire mesh or similar material shall be placed on the hot plate to prevent direct contact between the hot plate and mixing bowl.

3.8. Mixing Apparatus—Mechanical mixing is recommended. Any type of mechanical mixer may be used provided it can be maintained at the required mixing temperature and will produce a well-coated, homogeneous mixture of the required amount in the allowable time, and further provided that essentially all of the batch can be recovered. A metal pan or bowl of sufficient capacity and hand mixing may also be used.

3.9. Air Bath—The air bath for asphalt cutback mixtures shall be thermostatically controlled and shall maintain the air temperature at 25 ± 1°C (77° ± 2°F).

3.10. Thermometers—For determining temperatures of aggregates, asphalt binder, and asphalt mixtures. Armored-glass, dial type, or digital thermometers with metal stems are recommended. A range from 9.9 to 204°C (50 to 400°F) with sensitivity of 2.8°C (5°F) is required.

3.11. Balance—A balance meeting the requirements of M 231, Class G 2, for determining the mass of aggregates, binder and asphalt mixture.

3.12. Miscellaneous Equipment—Flat-bottom metal pans or other suitable containers for heating aggregates, containers (gill-type, beakers, pouring pots, or saucepan) for heating asphalt, flat bottom scoop for batching aggregates, steel trowel (garden type) or spatula for spading and hand mixing, gloves for handling hot equipment, paper disks, marking crayons for identifying specimens, and a large spoon for placing mixture in specimen molds.

4. PROCEDURE

4.1. Number of Specimens—Prepare at least three specimens for each combination of aggregates and bitumen content.

4.2. Preparation of Aggregates—Dry aggregates to constant mass at 105 to 110°C (221 to 230°F) and separate the aggregates by dry-sieving into the desired size fractions. The following size fractions are recommended:

- 25.0 to 19.0 mm (1 to 3/4 in.)
- 19.0 to 9.5 mm (3/4 to 3/8 in.)
- 9.5 mm to 4.75 mm (3/8 in. to No. 4)
4.3. **Determination of Mixing and Compacting Temperatures:**

4.3.1. The temperatures to which the asphalt binder and asphalt cutback must be heated to produce a viscosity of 170 ± 20 cSt shall be the mixing temperature.

4.3.2. The temperature to which asphalt binder must be heated to produce a viscosity of 280 ± 30 cSt shall be the compacting temperature.

4.3.3. From a composition chart for the asphalt cutback used, determine from its viscosity at 60°C (140°F) the percentage of solvent by mass. Also determine from the chart the viscosity at 60°C (140°F) of the asphalt cutback after it has lost 50 percent of its solvent. The temperature determined from the viscosity temperature chart to which the asphalt cutback must be heated to produce a viscosity of 280 ± 30 cSt after a loss of 50 percent of the original solvent content shall be the compaction temperature.

4.4. **Preparation of Mixtures (Laboratory Prepared):**

4.4.1. An initial batch shall be mixed for the purpose of “buttering” the mixture bowl and stirrers. This batch shall be emptied after mixing and the sides of the bowl and stirrers shall be cleaned of mixture residue by scraping with a small limber spatula but shall not be wiped with cloth or washed clean with solvent, except when a change is to be made in the binder or at the end of a run.

4.4.2. Weigh into separate pans for each test specimen the amount of each size fraction required to produce a batch that will result in a compacted specimen 63.5 ± 1.27 mm (2.5 ± 0.05 in.) in height (about 1200 g).

4.4.3. Mix the aggregate in each pan and place the pans on a hot plate or in the oven and heat to a temperature not exceeding the mixing temperature established in Section 4.3 by more than approximately 28°C (50°F) for asphalt mixtures and 14°C (25°F) for cutback asphalt mixes.

4.4.4. Heat, to the established mixing temperature, just sufficient asphalt material for the batch in a separate container.

4.4.5. Charge the mixing bowl with the heated aggregate. Form a crater in the dry-blended aggregate and weigh the preheated required amount of asphalt material into the mixture. For mixes prepared with cutback asphalt, introduce the mixing blade in the mixing bowl and determine the total mass of the mix components plus bowl and blade before proceeding with mixing. Care must be exercised to prevent loss of the mix during mixing and subsequent handling. At this point, the temperature of the aggregate and asphalt material shall be within the limits of the mixing temperature established in Section 4.3.

4.4.6. Mix the aggregate and asphalt material rapidly until thoroughly coated. To maintain proper mixing temperature, one of the methods described in Section 3.8 may be used.

4.4.7. Cure mixtures containing asphalt binder in accordance with R 30.

4.4.8. Cure asphalt cutback mixtures in a ventilated oven maintained at approximately 11.1°C (20°F) above the compaction temperature. Curing is to be continued in the mixing bowl until the precalculated weight of 50 percent solvent loss or more has been obtained. The mix may be stirred in a mixing bowl during curing to accelerate the solvent loss. However, care should be exercised to prevent loss of the mix. Weigh the mix during curing in successive intervals of 15 min initially and less than 10-min intervals as the weight of the mix at 50 percent solvent loss is approached.
4.5.  *Preparation of Mixture (Plant Produced):*

4.5.1.  Obtain the sample in accordance with T 168.

4.5.2.  Reduce the sample in accordance with R 47 to a sample size that will result in compacted specimens 63.5 ± 1.27 mm (2.5 ± 0.05 in.) in height as described in Section 4.4.2.

4.5.3.  Place the sample into a pan to a uniform thickness.

4.5.4.  Bring the asphalt mixture to the compaction temperature range by careful, uniform heating in an oven immediately prior to compaction.

4.6.  *Compaction of Specimens:*

4.6.1.  Thoroughly clean the specimen mold assembly and the face of the compaction hammer and heat them either in boiling water, on the hot plate, or in an oven, to a temperature between 93.3 and 148.9°C (200 and 300°F).

4.6.2.  Place a piece of filter paper or paper towel, cut to size, in the bottom of the mold before the mixture is introduced.

4.6.3.  Place the entire batch in the mold, and spade the mixture vigorously with a heated spatula or trowel 15 times around the perimeter and 10 times over the interior. Smooth the surface of the mix with a trowel to a slightly rounded shape. Remove the collar if necessary. Temperatures of the mixtures immediately prior to compaction shall be within the limits of the compaction temperature established in Section 4.3. If the temperature of the specimen is too high, allow the specimen to cool within the range of compaction temperatures; however, if the mixture is below compaction temperature, remove the mixture from the mold and replace it in the oven until the desired temperature is reached. Next, repeat the steps in this section. This process should not be repeated more than once. The material should be heated for the minimum time required to achieve the compaction temperature.

*Note 1*—Excessive heating times may cause oxidation and loss of volatiles and should be avoided.

4.6.4.  Replace the collar, then place a piece of filter paper or paper toweling cut to size on top of the mixture and place the mold assembly on the compaction pedestal in the mold holder, and unless otherwise specified, apply 50 or 75 blows with the compaction hammer with a free fall in 457.2 mm (18 in.). Hold the axis of the compaction hammer perpendicular to the base of the mold assembly during compaction. Remove the base plate and collar, and reverse and reassemble the mold. Apply the same number of compaction blows to the face of the reversed specimen.

4.6.5.  After compaction, remove the base plate, carefully extract the specimen from the mold and transfer to a smooth, flat surface.

4.6.6.  Allow the specimen to stand overnight at room temperature.

*Note 2*—In general, specimens shall be cooled as specified in Section 4.6.6. When more rapid cooling is desired, table fans may be used. Mixtures that lack sufficient cohesion to result in the required cylindrical shape on removal from the mold immediately after compaction may be cooled in the mold in air until sufficient cohesion has developed to result in the proper cylindrical shape.
5. KEYWORDS

5.1. Aggregate; asphalt binder; asphalt cutback; Marshall compaction hammer.

1 Formerly part of T 245. First published as a practice in 2015.
2

TDOT Supplemental Specifications
Subsection 401.02 (pg. 278) 10-8-18, Mineral Aggregate Surface – Materials, Remove Sodium Chloride from the materials list:

“401.02 Materials
Provide materials as specified in:
Aggregates, Class B .......................................................... 903.05.B
Calcium Chloride, Type I, Type 2, or Calcium Chloride Liquor ............ 921.02
The Engineer will accept aggregate for gradation as specified in 303.02.”

Subsection 401.06 (pg. 280) 10-8-18, Mineral Aggregate Surface – Method of Measurement, Remove 4. Sodium Chloride from the subsection:

“401.06 Method of Measurement
The Department will measure:
1. Mineral Aggregate Surface by the ton in accordance with 109.
2. Water added to the materials at the direction of the Engineer by the M.G. (1,000 gallons) using calibrated tanks or distributors, or accurate water meters.
3. Calcium Chloride by the ton in accordance with 303.14.D.
When measuring Mineral Aggregate Surface, the Department will deduct the weight of all surface moisture on the aggregate at the time of weighing in excess of 8%.”

Subsection 401.07 (pg. 280) 10-8-18, Mineral Aggregate Surface – Basis of Payment, Remove Sodium Chloride from the basis of payment list:

“The Department will pay for accepted quantities of Mineral Aggregate Surface, complete in place, at the contract prices as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Pay Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral Aggregate</td>
<td>Ton</td>
</tr>
<tr>
<td>Calcium Chloride</td>
<td>Ton</td>
</tr>
<tr>
<td>Water</td>
<td>MG</td>
</tr>
</tbody>
</table>
Subsection 402.03 (pg. 282) 5-27-16; revise 0.2 to 0.05 in the range as shown in the 2nd paragraph:

“The distributor shall be designed, equipped, maintained, and operated so that bituminous material at even heat may be applied uniformly on variable surface widths at readily determined and controlled rates from 0.05 to 0.5 gallons per square yard, with uniform pressure, and with an allowable variation from any specified rate of plus or minus 0.02 gallons per square yard.”

Subsection 403.02 (pg. 285-286) 10-8-18; Bituminous Materials, add RS-1, CRS-1 and remove emulsified from “Approved Emulsified Trackless Track”, update Table 403.02-1 to adjust temperature range required and add approved trackless tack information:

Provide materials as specified in:
Emulsified Asphalt, SS-1, SS-1h, CSS-1, CSS-1h, TST-1P, CQS-1h, CQS-1hp, RS-1, CRS-1………………..904.03 or Approved Trackless Tack from the QPL.

<table>
<thead>
<tr>
<th>Material</th>
<th>Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS-1, SS-1h, CSS-1, TST-1P, CQS1h, CQS-1hp, CSS-1h, Approved Trackless Tack from the QPL</td>
<td>70 to 160 °F Per Manufacturer’s Recommendation</td>
</tr>
</tbody>
</table>

Subsection 403.02 (pg. 285-286) 11-16-15; Bituminous Materials, update the reference to 904.03, add TTT-3 to Table 403.02-1:

“Emulsified Asphalt, SS-1, SS-1h, CSS-1, CSS-1h, TST-1P, CQS-1h, CQS-1hp…………………..904.03 or Approved Emulsified Trackless Tack from the QPL.

<table>
<thead>
<tr>
<th>Material</th>
<th>Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS-1, SS-1h, CSS-1, TST-1P, CQS-1h, CQS-1hp and CSS-1h</td>
<td>60 to 140 °F</td>
</tr>
</tbody>
</table>

Subsection 403.02 (pg. 285-286) 12-2-16; Bituminous Materials, remove trackless tack information from specifications and reference the QPL for approved Emulsified Trackless Tacks, remove trackless tacks from Table 403.02-1:

“Emulsified Asphalt, SS-1, SS-1h, CSS-1, CSS-1h, TST-1P, CQS-1h, CQS-1hp…………………..904.03 or Approved Emulsified Trackless Tack from the QPL.

<table>
<thead>
<tr>
<th>Material</th>
<th>Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS-1, SS-1h, CSS-1, TST-1P, CQS-1h, CQS-1hp and CSS-1h</td>
<td>60 to 140 °F</td>
</tr>
</tbody>
</table>
Table 403.02-1: Tack Coat Application Temperatures

<table>
<thead>
<tr>
<th>Material</th>
<th>Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS-1, SS-1h, CSS-1, TST-1P, CQS-1h, CQS-1hp and CSS-1h</td>
<td>60 to 140 °F</td>
</tr>
<tr>
<td>TTT-1</td>
<td>160 to 180 °F</td>
</tr>
<tr>
<td>TTT-2</td>
<td>120 to 160 °F</td>
</tr>
<tr>
<td>TTT-3</td>
<td>100 to 180 °F</td>
</tr>
</tbody>
</table>

Subsection 403.05 (pg. 286) 11-16-15; A. Emulsified Asphalt, Add the following paragraph at the end of the subsection:

“Take a minimum of 3 cores throughout the length of the project for informational tack coat shear testing. Include the underlying layer. Not required for mats less than one inch thick.”

Subsection 403.05 (pg. 287) 11-16-15; B. Test Strip, modify the 2nd paragraph to update the rate as 0.08 and 0.12:

“If placing the bituminous material upon a milled surface, apply the tack material at a rate of between 0.08 and 0.12 gallons of applied emulsion per square yard.”

Subsection 403.05 (pg. 287) 6-27-16; revise the last sentence of the 2nd paragraph:

“If placing the bituminous material upon a milled surface, apply the tack material at a rate of between 0.08 and 0.12 gallons applied emulsion per square yard.”

Subsection 403.05 (pg. 287), 11-6-17; Revise the 1st sentence of the 1st paragraph:

“When the Contract requires bituminous material for fog sealing of shoulders, provide emulsified asphalt meeting 403.02 or an item from QPL 40A.”

Subsection 404 (pg. 289-293) 1-6-17; Remove the entire subsection. All specifications regarding Double Bituminous Surface Treatment has been incorporated into subsection 405. All references shall be updated to subsection 405.

Subsection 405 (pg. 294-298) 1-6-17; replace subsection 405 with the following:

“405.01 Description

This work consists of constructing a bituminous seal coat consisting of one or more applications of bituminous material and cover aggregate.

MATERIALS

405.02 Materials

Provide materials as specified in:
Apply seal coat at a temperature range of 60 to 140 °F.

**EQUIPMENT**

405.03 Equipment

Provide a power broom or other mechanical sweeping equipment, equipment for heating bituminous material, a pressure distributor meeting the requirements of 402.03, pneumatic-tire and steel-wheel rollers, self-propelled mechanical aggregate spreading equipment that can be adjusted so as to spread accurately at the specified rate, and such other equipment and small tools as may be required to perform the work in a satisfactory manner.

**CONSTRUCTION REQUIREMENTS**

405.04 Limitations

Only apply bituminous material:

1. When the designated surface is dry, firm, and properly cured;
2. Between April 15 and October 1; and, unless otherwise directed,
3. When the ambient temperature in the shade and away from artificial heat is 70°F or more.

405.05 Preparing the Designated Surface

Before placing seal coat, clean all surfaces to be sealed by sweeping with a motorized broom to remove any loose material. Clean depressions and cracks not reached by the power broom using hand brooms or pressurized air.

Cover any utility installations to prevent adherence of the bituminous mixture. Suitable covering includes plywood disks, sand, craft paper, roofing felt or other approved methods. Remove the protective coverings before opening the road to traffic. The cost for these adjustments shall be included in the bid price for other items.

The Plans will indicate whether the surface is to be constructed on a treated or untreated subbase, a granular base, an asphalt base, or on an existing surface. The surface of the base or sub-base upon which the construction is to be placed shall meet the requirements of the applicable Section of Part 3, Bases and Subgrade Treatments, of these Specifications.

Condition existing surface, if called for on the Plans, as specified in 407.10. Condition existing mineral aggregate base as specified in 310.

Construct and maintain Prime Coat or Tack Coat, if shown on the Plans, as specified in 402 or 403, respectively.
405.06 Application

A. Applying Bituminous Material:

Have all equipment calibrated prior to starting work. The TDOT inspector shall be present during calibration to determine aggregate spread rate and distributor rates. Distributor trucks shall have proper calibration of spray equipment. Spray nozzles should be clean, properly angled, and appropriately sized for the desired application rate. Stop work if the distributor is not applying material properly, such as gaps in application or streaking.

Place a 500 ft. test strip for the bituminous seal coat at the beginning of the project to assure proper coverage and proper equipment calibration. The test section is to verify break time of emulsion and chip retention. The test strip shall be able to carry normal traffic within 3 hours. If normal traffic cannot be carried, the emulsion shall be adjusted and another test strip is required.

At least 14 working days before the scheduled start of construction of any bituminous seal coat, submit a sample of aggregate intended for use for the determination of the appropriate application rates of bituminous material and aggregate. Apply emulsified asphalt by pressure distributor at a uniform rate in accordance with Table 405.06-1 below. The exact rate will be established by the Engineer.

<table>
<thead>
<tr>
<th>Aggregate Size</th>
<th>Aggregate Spread Rate (lb/yd²)</th>
<th>Emulsion Shot Rate (gal/yd²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>25 – 30</td>
<td>0.30 – 0.45</td>
</tr>
<tr>
<td>78</td>
<td>22 – 28</td>
<td>0.28 – 0.38</td>
</tr>
<tr>
<td>8</td>
<td>20 – 25</td>
<td>0.20 – 0.35</td>
</tr>
<tr>
<td>89</td>
<td>17 – 23</td>
<td>0.17 – 0.28</td>
</tr>
</tbody>
</table>

Before beginning each spread, place building paper across the roadway surface with the forward edge exactly coinciding with the end of the preceding covered spread. Start distributors on the paper, the width of which shall allow the full force of all nozzles to be in effect before the forward edge of the paper is reached. If required by the Engineer, also stop the spread on building paper. Remove the paper immediately after its use, and dispose of properly. Immediately correct all defects in application.

The length of spread of bituminous material shall not exceed that which trucks loaded with cover material can immediately cover.

The spread of bituminous material shall not extend more than 6 inches wider than the width covered by the cover material. Do not allow the bituminous material to chill or otherwise impair retention of the cover material.

Do not allow traffic on the bituminous material until it has been covered with mineral aggregate.

Treat areas that are inaccessible to the distributor with either hand sprays or pouring pots as directed by the Engineer.
B. Application of Double Bituminous Surface Treatment:

First Application

Apply the first application of emulsified asphalt using pressure distributors at a uniform rate established by the Engineer within the range of 0.30 to 0.38 gallons per square yard. Apply each spread of bituminous material so as not to be more than 6 inches wider than the width covered by the immediate spread of cover aggregate. Each width of spread shall not be less than half the surface to be treated.

Before beginning each spread, place building paper across the roadway surface with the forward edge exactly coinciding with the end of the preceding covered spread. Start distributors on the paper, the width of which shall allow the full force of all nozzles to be in effect before the forward edge of the paper is reached. If required by the Engineer, also stop the spread on building paper. Remove the paper immediately after its use, and dispose of properly. Immediately correct all defects in application.

Treat areas that are inaccessible to the distributor with hand sprays or pouring pots as directed by the Engineer.

If treating less than the full width of the roadway, do not spread the aggregate on the inside 6 inches of either the first or second application until the adjacent lane has been treated. Immediately following each application, uniformly cover the applied bituminous material with Size No. 7 mineral aggregate that is reasonably free of surface moisture.

Spread the aggregate at a rate between 24 and 30 pounds per square yard, as established by the Engineer, using a self-propelled mechanical spreader; except on short projects of 1/2 mile in length or less, self-propelled mechanical spreading equipment will not be required. Back the truck on the aggregate being spread, without driving on or over uncovered bituminous material.

The length of bituminous material spread shall not exceed that which trucks loaded with cover material can immediately cover.

Second Application

Apply the second application of emulsified asphalt in the same manner as the first application, at a uniform rate established by the Engineer within the range of 0.20 and 0.35 gallons per square yard.

Spread mineral aggregate, Size No. 8, in the same manner as the first spread at a rate established by the Engineer within the range of 16 to 28 pounds per square yard.

Immediately after each spread of cover aggregate, broom to achieve uniform coverage. Use a power source, which is independent of the drive train that propels the equipment, to power the revolving brooms of mechanical sweeping equipment. Place additional aggregate by hand on thin or bare areas.
405.07 Spreading and Rolling Aggregate

A. Spreading

Immediately after bituminous material has been applied, no more than two minutes, spread and embed the mineral aggregate cover in the bituminous material. Spread the aggregate as close to the application of bituminous material as is practicable, and cover each distributor load applied immediately. Aggregates shall be moistened and visually damp at the time of placement.

Spread the aggregate in accordance with the rates specified in Table 405.06-1. The exact rate will be established by the Engineer. Back the truck on the aggregate being spread, without driving on or over uncovered bituminous material. If treating less than the full width of roadway, do not spread the aggregate on the inside 6 inches of the bituminous spread until the adjacent lane is treated. Immediately after spreading the aggregate, perform hand-brooming to achieve uniform coverage. Place additional aggregate by hand on thin or bare areas.

The speed of the spreader shall be such that the aggregates are not rolling over, and starting and stopping of the spreader is minimized. Use of previously used (swept) aggregates is not permitted.

B. Rolling – Bituminous Seal Coat

Immediately after distributing the aggregate, roll the entire surface by moving in a longitudinal direction, beginning at the outer edges and progressing toward the center of the roadway, with each trip of the roller overlapping the previous trip by half the width of the rear wheel. Perform initial rolling with a self-propelled pneumatic tire roller, and follow with steel-wheel rolling. The amount and sequence of rolling shall be as directed by the Engineer. Complete the initial rolling of the aggregate within 1 hour after applying the bituminous material.

Use power brooms to correct irregularities by sweeping the aggregates from areas of thick or heavy distribution to areas of thin or light distribution. Then continue rolling using both steel-wheel and pneumatic rollers until the aggregate is thoroughly embedded in the bituminous material. The Engineer may require additional rolling at a later date. Redistribute excess or loose aggregate that was thrown out of place.

Slow moving traffic may use the section or roadway upon which the aggregate has been spread.

Rolling and Curing – Double Bituminous Seal Coat

Immediately after spreading and brooming the cover aggregate, roll the entire surface, beginning at the edges and progressing to the center. Begin rolling within 30 minutes after spreading the aggregate. Perform initial rolling with a self-propelled pneumatic tire roller, and follow with steel-wheel rolling. The amount and sequence of rolling shall be as directed by the Engineer.

Allow the first application of bituminous material and aggregate to cure for as long as deemed necessary by the Engineer before beginning the second application. Immediately before the second application of bituminous material, roll the surface with a steel-wheel roller.

For the second application of bituminous material and cover aggregate, repeat the same rolling and curing procedures as required for the first application.
The Contractor may allow slow-moving traffic to use sections of the roadway where the bituminous material has been covered with mineral aggregate.

**405.08 Shoulders**

Restore shoulders that have been disturbed by the Contractor’s construction operations at no cost to the Department. Remove all objectionable material placed on the shoulders by the Contractor as directed by the Engineer.

Construct shoulders, when specified, as provided for under 208.

**405.09 Maintenance and Protection**

Maintain in a satisfactory condition each completed section of seal coat until the entire Project is complete. Maintenance shall include making repairs where failures occur, and maintaining the seal coat in a smooth uniform condition; and brooming, dragging, and rolling when required.

After the final application, maintain the work in a satisfactory condition for at least 10 calendar days. If all other requirements of the Contract have been fulfilled, the Department will not charge working time during the 10-day maintenance period against the Contract time.

For final cleanup, sweep up all excessive quantities of loose, dislodged cover aggregate that may have collected along the edge of the completed seal coat, and dispose of this material as directed by the Engineer.

**405.10 Method of Measurement**

The Department will measure Mineral Aggregate and Bituminous Material by the ton in accordance with 109. The Department may use net certified weights as a basis of measurement for mineral aggregate, subject to correction for aggregate that is lost, wasted, or otherwise not incorporated into the Work.

**405.11 Basis of Payment**

The Department will pay for accepted quantities of Bituminous Seal Coat, complete in place, at the contract prices as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Pay Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bituminous Material</td>
<td>Ton</td>
</tr>
<tr>
<td>Mineral Aggregate</td>
<td>Ton</td>
</tr>
</tbody>
</table>

The Department will measure and pay for the work required to prepare the designated surface, as provided for under 405.05, in accordance with the applicable Section or Subsection under which the work is performed.”
Subsection 405.05 (pg. 295) 5-14-18; Add the following as the second paragraph:

“Before placing seal coat, clean all surfaces to be sealed by sweeping with a motorized broom to remove any loose material. Clean depressions and cracks not reached by the power broom using hand brooms or pressurized air.

Remove pavement markers and adhesives. Abrade all types of existing striping. Work shall be accomplished without the pavement being gouged or damaged and in a manner which ensures the bituminous treatment will adhere in all areas applied. Work shall be performed to the satisfaction of the Engineer.”

Subsection 407.02 (pg. 300-301) 12-2-16; Replace the 4th paragraph:

“If anti-stripping additive, other than hydrated lime, meeting 921.06.B.1 is required, use approved in-line blending equipment, as specified in 407.04.A.6, to add it at the mixing plant or inject it at the asphalt terminal. Manufacture’s documentation that asphalt binders will continue to meet requirements listed in Subsection 904 after the anti-stripping additive is added shall be provided by the contractor with the mix design submittal. For mix designs submitted more than six months in advance, the documentation shall be resubmitted prior to use of the mix design with updated test results.”

Subsection 407.02 (pg. 300) 11-16-15; Materials, add the following at the end of the fourth paragraph:

“If anti-stripping additive, other than hydrated lime, meeting 921.06.B.1 is required, use approved in-line blending equipment, as specified in 407.04.A.6, to add it at the mixing plant or inject it at the asphalt terminal. Provide manufacture’s documentation ensuring asphalt binders will continue to meet requirements listed in Subsection 904 after anti-stripping additives are added.”

Subsection 407.03 D.2.h.3 (pg. 308), 6-24-19; Mix Design/Production Verification; Revise the 1st & 2nd paragraph:

(3) Place no more than 500 tons of mix until the verification testing, with the exception of TSR, is complete. Without complete test results, the Contractor, at its risk, may continue and mixture may be produced and placed mixture in excess of the first 500 tons; however, all mixture will be subject to price adjustment or removal at the discretion of the Engineer if the test results do not comply with the specifications.

Proceed, if the test results for the produced mix are within the limits required for production. The limits required for production are defined as meeting all of the following:

(a) Meets all mix design requirements as specified in Table 407.03-2,
(b) Gradation and Asphalt Cement Content of the mix are within the 90% pay factor for a single test per Table 407.20-2, and mix density requirements are met,
(c) The average compacted density of the test strip meets requirements per Table 407.15-1.
Subsection 407.03 E. 1. (pg. 313) 10-8-18, Tensile Strength Ratio, modify the second paragraph:

“1. **Tensile Strength Ratio.** Perform testing for stripping and moisture susceptibility of the mixture according to ASTM D 4867, Standard Test Method for Effect of Moisture on Asphalt-Concrete Paving Mixtures For all mixtures requiring design, except OGFC, follow ASTM D4867. For OGFC follow ASTM D4867 except as noted:

- Modify step 8.6.1 so that the three conditioned samples are subjected to a partial vacuum of 26 inches Hg for 10 minutes to whatever degree of saturation achieved
- Subject the 3 condition samples to one freeze thaw cycle per note 6 listed in ASTM D4867 8.7. except as noted:
  - After 15h in freezer, remove samples and immediately immerse the still wrapped specimen in 77°F water for 2 hours
  - After 2 hours remove specimen from water bath and remove wrapping from specimen then immerse sample in 140°F water bath for 24 hours.

All specimens tested for stripping and moisture susceptibility shall meet the criteria specified in Table 407.03-4.”

Subsection 407.06 (pg. 327), 5-18-15; - A. Pavers. Replace the entire first paragraph with the following:

“Bituminous pavers shall be self-contained, power-propelled units provided with an activated screed, equipped to be heated, and capable of spreading and finishing courses of bituminous plant mix material in lane widths applicable to the specified typical section and thickness shown on the Plans. All screed extensions shall be full assembly extensions, including activated and heated screeds. Pavers shall include throw-back blades, reverse augers, or equivalent to place mix beneath the auger gearbox. Auger extensions shall be incorporated in a manner such that the maximum distance from the augers to the end plate shall be 18 inches. Screed extensions may extend beyond the 18-inch maximum from auger extensions only when extending for short-term temporary deviations in pavement width such as driveways. Do not use strike-off boxes, with the exception of sections with continuously varying width.”

Subsection 407.09 (pg. 329-331), 5-14-18; Revise the following: 3. Add two sentences as the end of the paragraph, 4. Remove the first sentence, add two sentences as new first and second sentence, Add second paragraph as shown:

“3. Do not place bituminous plant mix, with a compacted thickness of 1.5 inches or less, between November 30 and April 1. Do not place bituminous plant mix, with a compacted thickness greater than 1.5 inches, between December 15 and March 16. Only place 411-TL, 411-TLD, and 411-OGFC mixtures when the pavement surface temperature and the ambient air temperature are a minimum of 55°F and rising; limit placement to the period from April 1 to November 1. If the temperature meets the above requirements, outside of normal paving season, a request for a seasonal limitation waiver may be submitted for Departmental consideration. Requests shall be submitted in writing at least one week before the anticipated need.

4. If determined necessary by the Department, the Contractor may request a variance from the above required temperatures and seasonal limitations to pave at lower temperatures by submitting
a Cold Weather Paving and Compaction Plan. All projects requiring a Cold Weather Paving and Compaction Plan shall utilize Intelligent Compaction to demonstrate proper coverage and compaction temperature at no additional cost to the Department; with the exception of small quantity projects, such as, but not limited to, bridge approaches, intersections, and temporary traffic shifts. Upon completion, the documentation showing appropriate coverage and compaction temperature shall be provided to the Department. Submit requests in writing at least one week before the anticipated need, and include a Paving and Compaction Plan for Cold Weather that meets the Department’s Procedure. The plan shall identify what practices and precautions the Contractor intends to use to ensure the mixture is placed and compacted to meet the specifications. The plan shall include compaction cooling curves estimating the time available for compaction, the intended production, haul, and compaction rates, with paver and roller speeds estimated. The Contractor may consider using such practices as the addition of rollers, reduced production and paving rates, insulated truck beds, and heating the existing surface.

In no cases will a cold weather paving and compaction plan or seasonal limitation waiver be approved for 411-OGFC, 411-TL, or 411-TLD.

If the specified densities are not obtained, stop all paving operations and develop a new plan. All mixture failing to meet specifications will be subject to price adjustments or removal and replacement at no cost to the Department.”

Subsection 407.11 (pg. 332) 12-2-16; Add the following to the paragraph below Table 407.11-1:

“Minimum temperature for OGFC mixes shall be 280º.”

Subsection 407.14 (pg. 335) 10-8-18; modify paragraph 3. 1st sentence by adding lift thickness:

“establish lift thickness or line, grade, and elevation”

Subsection 407.15, C. Test Strips. (pg. 340-341) 11-16-15; Add the following paragraph after the 7th paragraph of the subsection:

“Take an additional 3 cores after placement of the surface layer on the tack coat test strip described in subsection 403.05.B. Include the underlying pavement layer for shear testing. These cores will be for informational testing only. Not required for mats less than one inch thick”

Subsection 407.15 (pg. 341) 6-27-16; remove the 2nd sentence of the 8th paragraph:

“Take cores on the test strip at ten randomly selected locations as designated by the Engineer. Provide these cores to the Department for use in calibrating the nuclear gauge and to verify that the average density of the test strip meets the density requirements of the specifications. The Department will report all densities using the corrected nuclear gauge readings. Correction factors are specific to the nuclear gauges used during the test strip construction. If a different nuclear gauge needs to be used for acceptance, it will be necessary to cut new cores from the ongoing pavement construction to calibrate the new gauge.”
Subsection 407.15 (pg. 341) 12-2-16; remove “randomly selected” from 1st sentence of the 8th paragraph as follows:

“Take cores on the test strip at ten locations as designated by the Engineer.”

Subsection 407.15 A. 3. c. (pg. 337-338) 5-15-17; update 10,000 square yards to 1,000 tons:

“c. Projects containing less than 1,000 tons or bituminous pavement.”

Subsection 407.15 A. and B. (pg. 337-342) 10-8-18; A. Add Roller Requirements by Mix Type, modify 1., 2., and 4., B. Modify Tables to condense into Table 407.15 – 1 Density Requirements for Bituminous Pavements, modify 1st sentence of the 1st paragraph below Table 407.15:

407.15 Compaction

A. General

After spreading and striking-off the bituminous mixture and adjusting surface irregularities, thoroughly compact the mixture using methods approved by the Engineer and that are capable of achieving the specified density while the material is in a workable condition. When no density requirements are specified, use a system of compaction for roadway pavements that has previously produced the required bituminous pavement densities. The Engineer may require a control strip and random density samples to evaluate the system.

In general, accomplish compaction using a combination of the equipment specified in 407.07. As a minimum, meet the following roller requirements, but increase the number of rollers if the required results are not being obtained.

<table>
<thead>
<tr>
<th>Mix Type</th>
<th>Roller Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>411-TL, 411-TLD, 411-TLE, 307-CS (when paved as a continuous layer)</td>
<td>2 Rollers (unspecified)</td>
</tr>
<tr>
<td>411-OGFC</td>
<td>2 rollers (both rollers shall be static steel double drum, 10 Ton minimum)</td>
</tr>
<tr>
<td>Any mix used for scratch paving</td>
<td>2 rollers (breakdown shall be pneumatic)</td>
</tr>
</tbody>
</table>
1. If the compaction effort is detrimental to the quality of the mat, immediately stop and re-evaluate rolling patterns and equipment. To modify the roller train from that which is specified for the mix, submit to the engineer a written request of the rollers to be substituted and a narrative explanation of how the specified equipment has been detrimental to the quality of the pavement.

2. The Department will only consider requests for substitution of equipment when it is shown that best practices are being followed and that the problem is not due to improper operation or poor maintenance of the equipment. If this request is approved by the Engineer, a new test strip and roller pattern shall be established.

3. With the Engineer’s approval, the Contractor may reduce the minimum number of rollers listed above to one roller of either the steel-wheel or vibratory type on the following types of construction and projects:
   a. Shoulder construction,
   b. Incidental construction such as bridge approaches and driveways, and
   c. Projects containing less than 10,000 square yards of bituminous pavement.

4. Compaction of 411-OGFC mixtures shall consist of a minimum of two passes before the material temperature has fallen below 185 °F. Unless otherwise directed by the Engineer, begin rolling at the low side and proceed longitudinally parallel to the road centerline. When paving in echelon, or abutting a previously placed lane, roll the longitudinal joint first, followed by the regular rolling procedure. When paving in echelon, rollers shall not compact within 6 inches of an edge where an adjacent lane is to be placed. Operate rollers at a slow uniform speed with the drive wheels nearer the paver, and keep the rollers as nearly as possible in continuous operation. Continue rolling until all roller marks are eliminated. Do not park rollers on the bituminous pavement.

   To prevent adhesion of the mixture to the rollers, keep the wheels properly moistened with water or water mixed with very small quantities of detergent or other approved material. Limit excess use of liquid.

   Do not refuel rollers on bituminous pavements.

   Along forms, curbs, headers, walls and other places not accessible to the rollers, compact the mixture thoroughly using hot hand tampers, smoothing irons, or with mechanical tampers. On depressed areas, the Contractor may use a trench roller to compact the mix.

B. Density Requirements

Meet the applicable density requirements specified in Tables 407.15-1.
Table 407.15-1: Density Requirements for Bituminous Pavement

<table>
<thead>
<tr>
<th>Mix Type</th>
<th>% of Maximum Theoretical Density (Lot Average)</th>
<th>No Single Test Less Than, % (Sub Lot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Lanes ADT &lt; 1,000 A, B, BM, BM2, C, CW, D, E</td>
<td>90.0</td>
<td>87.0</td>
</tr>
<tr>
<td>Travel Lanes 1,000&lt;ADT&lt;3,000 A, B, BM, BM-2, C, CW, D, E</td>
<td>91.0</td>
<td>89.0</td>
</tr>
<tr>
<td>Travel Lanes ADT&gt;3,000 A, B, BM, BM-2, C, CW, D, E</td>
<td>92.0</td>
<td>90.0</td>
</tr>
<tr>
<td>Travel Lanes and Shoulders Any ADT CS, TL, TLD, TLE, OGFC</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Shoulders B, BM, BM-2, D, E</td>
<td>88.0</td>
<td>85.0</td>
</tr>
</tbody>
</table>

Correct sublots that test below the minimum density so that the density of the area is equal to or above the minimum, at which point it can be used to determine the average density of the lot. Do not place any successive layers until the area has been corrected. As necessary to determine the classification of open graded or dense graded mixes and to measure segregation, use AASHTO T 269 or ASTM D3203.

Repair or replace defective mixture to the satisfaction of the Engineer and at no cost to the Department.

The Department will perform density testing in accordance with 407.20.B.5.

**Subsection 407.20 A.** (pg. 345), 11-6-17; Revise the second paragraph as follows:

“The Department will pay for liquid anti-strip additive and hydrated lime anti-strip additive based on certified documentation of material costs not to exceed $15 per gallon and $90 per ton, respectively.”

**Subsection 407.20** (pg. 346) 5-18-15; Basis of Payment; B. Acceptance of Mixture; Modify the last paragraph to revise 500 tons to 1000 tons:

“When the total plan quantity of any mix is less than 1000 tons, the Department will accept the mix on the basis of visual inspection and Contractor Quality Control certification. The Department may run extraction, gradation analysis, or other tests deemed necessary for acceptance purposes.”
Subsection 407.20 B.1 (pg. 346), 5-13-19; Acceptance of the Mixture, General; Revise 2nd & 3rd paragraph:

The Engineer will accept bituminous mixture at the plant with respect to gradation and asphalt content, on a lot basis. A standard size lot at the asphalt plant will consist of a continuous day or night’s shift’s production. For night jobs that does not start a new lot over at Midnight. The number of sublots in a lot will vary from n=1 to n=4 according to Table 407.20-1.

When the total plan quantity of any mix is less than 1000 tons, the Department will accept the mix on the basis of visual inspection and Contractor Quality Control certification. If the daily production of any mix is less than 100 tons, no tests will be required for that quantity of mix. The Department may run extraction, gradation analysis, or other tests deemed necessary for acceptance purposes.

Subsection 407.20 (pg. 348) 10-8-18; Table 407.20-2, add OGFC information to table:

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Pay Factor</th>
<th>Average Arithmetic Deviation of the Lot Acceptance Test from the JMF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 Test</td>
</tr>
<tr>
<td>All mixes except 411-OGFC</td>
<td>1.00</td>
<td>0.00-0.30</td>
</tr>
<tr>
<td>Asphalt Cement Content (1)</td>
<td>0.95</td>
<td>0.31-0.35</td>
</tr>
<tr>
<td>(Extraction or ignition oven)</td>
<td>0.90</td>
<td>0.36-0.40</td>
</tr>
<tr>
<td>411-OGFC only</td>
<td>1.00</td>
<td>0.00-0.30</td>
</tr>
<tr>
<td>Asphalt Cement Content</td>
<td>0.90</td>
<td>0.31-0.35</td>
</tr>
<tr>
<td>(Extraction or ignition oven)</td>
<td>0.80 (2)</td>
<td>over 0.40</td>
</tr>
<tr>
<td>Gradation</td>
<td>1.00</td>
<td>0.00-6.50</td>
</tr>
<tr>
<td>3/8 inch sieve and larger</td>
<td>0.95</td>
<td>6.51-7.08</td>
</tr>
<tr>
<td></td>
<td>0.90</td>
<td>7.09-7.66</td>
</tr>
<tr>
<td></td>
<td>0.80 (2)</td>
<td>over 7.66</td>
</tr>
<tr>
<td>Gradation No. 4 sieve (3)</td>
<td>1.00</td>
<td>0.00-4.62</td>
</tr>
<tr>
<td></td>
<td>0.95</td>
<td>4.63-5.20</td>
</tr>
<tr>
<td></td>
<td>0.90</td>
<td>5.21-5.77</td>
</tr>
<tr>
<td></td>
<td>0.80 (2)</td>
<td>over 5.77</td>
</tr>
<tr>
<td>Characteristics</td>
<td>Pay Factor</td>
<td>Average Arithmetic Deviation of the Lot Acceptance Test from the JMF</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>------------</td>
<td>---------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 Test</td>
</tr>
<tr>
<td>Gradation No. 8, 16, 30 &amp; 50 sieves (^{(1)})</td>
<td>1.00</td>
<td>0.00-3.80</td>
</tr>
<tr>
<td></td>
<td>0.95</td>
<td>3.81-4.46</td>
</tr>
<tr>
<td></td>
<td>0.90</td>
<td>4.47-5.12</td>
</tr>
<tr>
<td></td>
<td>0.80 (^{(2)})</td>
<td>over 5.12</td>
</tr>
<tr>
<td>Gradation No. 100 &amp; 200 sieves (^{(3)})</td>
<td>1.00</td>
<td>0.00-1.80</td>
</tr>
<tr>
<td></td>
<td>0.95</td>
<td>1.81-2.00</td>
</tr>
<tr>
<td></td>
<td>0.90</td>
<td>2.01-2.20</td>
</tr>
<tr>
<td></td>
<td>0.80 (^{(2)})</td>
<td>over 2.20</td>
</tr>
</tbody>
</table>

\(^{(1)}\) Does not apply to 307 Grading A, AS, or ACRL mixes.

\(^{(2)}\) If approved by the Engineer, the Contractor may accept the indicated partial pay. The Department may require removal and replacement at no cost. The Contractor may remove and replace at no cost to the Department at any time.

\(^{(3)}\) When there is more than one reduced payment relating to gradation in 1 lot of material, only the greatest reduction in payment will be applied. Reductions applicable for any other reason will be cumulative.

**Subsection 407.20** (pg. 348) 11-16-15; Table 407.20 – 2, make the following changes:

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Pay Factor</th>
<th>Average Arithmetic Deviation of the Lot Acceptance Test from the JMF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 Test</td>
</tr>
<tr>
<td>Asphalt Cement Content (^{(1)}) (Extraction or ignition oven)</td>
<td>1.00</td>
<td>0.00-0.30</td>
</tr>
<tr>
<td></td>
<td>0.95</td>
<td>0.31-0.35</td>
</tr>
<tr>
<td></td>
<td>0.90</td>
<td>0.36-0.40</td>
</tr>
<tr>
<td></td>
<td>0.80 (^{(2)})</td>
<td>over 0.40</td>
</tr>
<tr>
<td>Gradation 3/8 inch sieve and larger</td>
<td>1.00</td>
<td>0.00-6.50</td>
</tr>
<tr>
<td></td>
<td>0.95</td>
<td>6.51-7.08</td>
</tr>
<tr>
<td></td>
<td>0.90</td>
<td>7.09-7.66</td>
</tr>
<tr>
<td></td>
<td>0.80 (^{(2)})</td>
<td>over 7.66</td>
</tr>
<tr>
<td>Gradation No. 4 sieve (^{(3)})</td>
<td>1.00</td>
<td>0.00-4.62</td>
</tr>
<tr>
<td></td>
<td>0.95</td>
<td>4.63-5.20</td>
</tr>
<tr>
<td></td>
<td>0.90</td>
<td>5.21-5.77</td>
</tr>
<tr>
<td></td>
<td>0.80 (^{(2)})</td>
<td>over 5.77</td>
</tr>
</tbody>
</table>
Subsection 407.20 (pg. 349) 10-8-18; B.5, Add the sentence as the next to last sentences of the 1st paragraph:

“Acceptance for Mix Density on the Roadway. The Department will apply a deduction in payment, not as a penalty but as liquidated damages, for failure to meet the density requirements specified in 407.15. As soon as practicable after the final rolling is completed on each lot, the Department will perform 5 density tests at locations determined by the Engineer, and will compute an average of all such tests. Deductions for failure to meet density requirements will be computed to the nearest 0.1% as a percentage of the total payment otherwise due for each lot. The percent of total payment to be deducted will be 5 times the percent the average in-place density for each lot that fails to meet 407.15. The Department will make deductions in monies due the Contractor for failure to meet the density requirements under the item for Density Deduction. The Department will conduct acceptance testing for density in accordance with ASTM D2950 unless otherwise specified. For projects with total project tonnage per mix type less than 2,000 tons (not including small quantity jobs as defined in 407.20.B.1) the department may alternatively calculate in place density by cores (AASHTO T-166), in this case no cores will be taken for gauge correlation on the test strip. The Department inspector will be a certified Asphalt Roadway Technician.”

Subsection 407.20 (pg. 350) 10-7-19; B.5. Acceptance for Mix Density on the Roadway, Revise the last sentence in the 1st paragraph:

“Acceptance for Mix Density on the Roadway. The Department will apply a deduction in payment, not as a penalty but as liquidated damages, for failure to meet the density requirements specified in 407.15. As soon as practicable after the final rolling is completed on each lot, the Department will perform 5 density tests at locations determined by the Engineer, and will compute an average of all such tests. Deductions for failure to meet density requirements will be computed to the nearest 0.1% as a percentage of the total payment otherwise due for each lot. The percent of total payment to be deducted will be 5 times the percent the average in-place density for each lot that fails to meet 407.15. The Department will make deductions in monies due the Contractor for failure to meet the density requirements under the item for Density Deduction. The Department will conduct acceptance testing for density in accordance with ASTM D2950 unless otherwise specified. The Department inspector conducting the density tests shall be a certified Nuclear Gauge Field Technician.”

Subsection 407.20 (pg. 350) 11-16-15; B. 5. Acceptance for Mix Density on the Roadway, Replace the entire 2nd paragraph with the following:

“For density testing purposes, the Department will divide the pavement into lots of 1,000 tons. Five density tests will be performed in each lot and the average results compared with the requirements specified in Tables 407.15-1 to 407.15-4. At the beginning of a project or at any time it is deemed advisable, the Department may consider smaller lots to evaluate compaction methods or for other reasons as approved or directed by the Engineer.”
Subsection 411.03 (pg. 357) 10-8-18; B. Proportioning, modify table 411.03-1 to add TLE requirements:

Table 411.03-1: Proportions of Total Mixture, Percent by Weight

<table>
<thead>
<tr>
<th>Surface Course</th>
<th>Effective Combined Mineral Aggregate</th>
<th>Asphalt Cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grading D</td>
<td>93.0 - 94.3</td>
<td>5.7 - 7.0 (1)</td>
</tr>
<tr>
<td>Grading E (2)</td>
<td>93.0 - 94.3</td>
<td>5.7 - 7.0 (1)</td>
</tr>
<tr>
<td>Grading E (shoulders)</td>
<td>92.0 - 94.7</td>
<td>6.0 - 6.5 (1)</td>
</tr>
<tr>
<td>Grading TL</td>
<td>92.5 - 94.3</td>
<td>5.7 - 7.5 (1)</td>
</tr>
<tr>
<td>Grading TLD</td>
<td>93.0 - 94.3</td>
<td>5.7 - 7.0 (1)</td>
</tr>
<tr>
<td>Grading TLE</td>
<td>93.0 - 94.3</td>
<td>5.7 - 7.0 (1)</td>
</tr>
<tr>
<td>Grading OGFC</td>
<td>92.0 - 94.0</td>
<td>6.0 - 8.0 (1)</td>
</tr>
</tbody>
</table>

(1) If the effective combined specific gravity of the aggregate exceeds 2.80, the above proportions may be adjusted as directed by the Engineer. The upper limit for flow values shall not apply to mixes with modified asphalt liquids.

(2) The minimum allowable asphalt cement content for 411E low volume mixtures is 5.3%.

Subsection 411.03 (pg. 358-359) 10-8-18; B. Proportioning: 2. Grading E, modify subsection and Table 411.03-3 to add TLE requirements, remove riding surface phrase:

2. **Grading E and TLE.** In addition to the other requirements of these Specifications, the composition of the mineral aggregate shall be such that, when combined with the required amount of bitumen, the resultant mixture will meet Table 411.03-3.

Table 411.03-3: Mixture Properties (High vs. Low Volume Roads)

<table>
<thead>
<tr>
<th>Mix</th>
<th>Traffic Volume</th>
<th>Stability Minimum LB-FT (1, 3)</th>
<th>Flow 0.01 inch (2)</th>
<th>Design Void Content % (1)</th>
<th>Production Void Content % (1)</th>
<th>VMA, Min % (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>411E</td>
<td>High Volume (ADT &gt; 1,000)</td>
<td>2,000</td>
<td>8 - 16</td>
<td>4.0 ± 0.2</td>
<td>3 - 5.5</td>
<td>14</td>
</tr>
<tr>
<td>411TLE</td>
<td>Low Volume (ADT ≤ 1,000)</td>
<td>1,500</td>
<td>8 - 16</td>
<td>3.5 ± 0.5</td>
<td>2 - 5</td>
<td>n/a</td>
</tr>
</tbody>
</table>

(1) Tested according to AASHTO T 245 with 75 blows of the hammer on each side of the test specimen, using a Marshall Mechanical Compactor.

(2) Flow will only be required when using a non-modified binder (PG 64-22 or 67-22)

(3) Minimum stability for shoulder mixes will be 1,500 lb-ft and optimum asphalt cement content for shoulder mixes shall be as directed by the Regional Materials Supervisor.
**Subsection 411.03** (pg. 358-359) 10-8-18; C. Recycled Asphalt Pavement and Recycled Asphalt Shingles: modify Table 411.03-6 to add TLE requirements:

**Table 411.03-6: Use of Recycled Asphalt Pavement**

<table>
<thead>
<tr>
<th>Mix Type</th>
<th>% RAP (Non-processed)</th>
<th>Maximum % RAP (Processed)</th>
<th>Maximum % RAP Processed and Fractionated</th>
<th>Maximum Particle Size (inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>411D (PG64-22, PG67-22)</td>
<td>0</td>
<td>15</td>
<td>20</td>
<td>1/2</td>
</tr>
<tr>
<td>411D (PG70-22, PG76-22, PG82-22)</td>
<td>0</td>
<td>10</td>
<td>15</td>
<td>1/2</td>
</tr>
<tr>
<td>411E &amp; 411TLE (Roadway)</td>
<td>0</td>
<td>15</td>
<td>20</td>
<td>1/2</td>
</tr>
<tr>
<td>411E &amp; 411TLE (Shoulder)</td>
<td>15</td>
<td>30</td>
<td>35</td>
<td>1/2</td>
</tr>
<tr>
<td>411TL (PG64-22, PG67-22)</td>
<td>0</td>
<td>15</td>
<td>15</td>
<td>5/16</td>
</tr>
<tr>
<td>411TL (PG70-22, PG76-22, PG82-22)</td>
<td>0</td>
<td>10</td>
<td>10</td>
<td>5/16</td>
</tr>
<tr>
<td>411TLD (PG64-22, PG67-22)</td>
<td>0</td>
<td>15</td>
<td>15</td>
<td>5/16</td>
</tr>
<tr>
<td>411TLD (PG70-22, PG76-22, PG82-22)</td>
<td>0</td>
<td>10</td>
<td>10</td>
<td>5/16</td>
</tr>
</tbody>
</table>

(1) “Non-processed” refers to RAP that has not been crushed and screened or otherwise sized such that the maximum recycled material particle size is less than that listed above prior to entering the dryer drum.

(2) “Processed” refers to RAP that has been crushed and screened or otherwise sized such that the maximum recycled material particle size is less than that above prior to entering the dryer drum.

(3) “Fractionated” refers to RAP that has been processed over more than one screen, producing sources of various maximum particle sizes (e.g., 3/4 to 1/2 inch, 1/2 inch to #4, etc.). The Contractor may use the larger percentages of fractionated RAP specified only if individual fractions of two different maximum particle size are introduced into the plant as separate material sources for increased control.

**Subsection 411.03** (pg. 363) 11-16-15; 2. Recycled Asphalt Shingles (RAS), change 5% to 3% in the 1st sentence of the 1st paragraph.

“Recycled Asphalt Shingles (RAS) may be included to a maximum of 3% of the total weight of mixture.”
Subsection 411.03 B. Anti-strip Additive (pg. 365) 6-27-16; revise the 2nd paragraph:

“Mix an approved anti-strip agent with the asphalt cement at the dosage as specified in 921.06.B.”

Subsection 411.09 (pg. 367), 5-13-19; Method of Measurement; Revise Table 411.09-1:

<table>
<thead>
<tr>
<th>Mix Type</th>
<th>Asphalt Content, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>411-D</td>
<td>5.9</td>
</tr>
<tr>
<td>411-E Roadway</td>
<td>6.3</td>
</tr>
<tr>
<td>411-E Shoulder</td>
<td>6.3</td>
</tr>
<tr>
<td>411-TL</td>
<td>6.3</td>
</tr>
<tr>
<td>411-TLD</td>
<td>5.9</td>
</tr>
<tr>
<td>411-TLE Roadway</td>
<td>5.9</td>
</tr>
<tr>
<td>411-TLE Shoulder</td>
<td>5.9</td>
</tr>
<tr>
<td>411-OGFC</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Subsection 414.02 (pg. 369) 11-16-15; Materials, add the following paragraph to the end of the subsection:

“Ensure that no deleterious material is introduced into aggregate stockpiled at project site.”

Subsection 414.02 (pg. 369) 11-6-17; Revise the last sentence:

“For a slurry seal, use a Type CQS-1h emulsified asphalt. For micro-surfacing use a type CQS-1hp or CSS-1hp emulsified asphalt.”

Subsection 414.06 (pg. 379-382) 5-14-18; Remove B. 3. a., update b. to a. and revise as follows:

“B. Quality Control

3. Documentation. Maintain a lot sheet as follows:

a. Lot Sheet. Divide the Project into lots of each day’s production. For each lot, maintain a lot sheet, providing the following information:

   (1) Contract Number, Route,
   (2) Date, Air Temperature, Pavement Surface Temperature
   (3) Control Settings, Calibration Values, Unit Weight of Emulsion (pounds per gallon), Percent Residue in Emulsion
(4) Beginning and Ending Log Miles
(5) Computer display readings for material usage (Beginning, Ending, and Total)
(6) Length, Width, Total Area (square yards) of the construction completed for the day
(7) Aggregate used (dry ton) Asphalt Emulsion used (ton), additives (gallon), water (gallon), and/or Portland Cement (ton)
(8) Application Rate of asphalt emulsion, Combined Application Rate (pounds per square yard)
(9) Mix Design (Percent Portland cement, Percent Emulsion, Percent Asphalt Cement)
(10) Calibration Forms
(11) Contractor’s Authorized Signature

Subsection 414.12 (pg. 384) 10-8-18, Basis of Payment, add the following as the last sentence of the paragraph:

“The Department will pay for accepted quantities, determined in accordance with 414.11, at the contract prices, complete in place, which payment shall be full compensation for all equipment, materials, labor and incidentals necessary to complete the work. A price adjustment for Loss on Ignition (LOI) shall be applied on a project basis per 407.20.C.3.”
UPCOMING 400SS CHANGES

Subsection 407.03 E (pg. 290), X-XX-19; Testing Procedures; Revise Table 407.03-04: Criteria for Stripping and Moisture Susceptibility:

<table>
<thead>
<tr>
<th>Asphalt Cement</th>
<th>Minimum Tensile Strength</th>
<th>Minimum TSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polymer Modified</td>
<td>100 psi</td>
<td>80%</td>
</tr>
<tr>
<td>Non-Polymer Modified</td>
<td>80 psi</td>
<td>80%</td>
</tr>
<tr>
<td>411 OGFC</td>
<td>50 psi</td>
<td>80%</td>
</tr>
</tbody>
</table>

Subsection 407.20 B.3 (pg. 347-348), X-XX-19; Acceptance of the Mixture; Revise 3rd paragraph:

Monthly, per mixture, the Engineer shall determine the correction factor for the ignition oven used for acceptance of the mixture per AASHTO T 308 and adjust the Asphalt Cement content for acceptance of the mixture accordingly. Keep records of all correction factors for all mixtures. Adjusted payment for asphalt content and gradation will be based on the ignition furnace results as specified in Table 407.20-2. Use of this alternative equipment shall be at no additional cost to the Department.
3

TDOT Standard Operating Procedures
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Quality Assurance Program for the Sampling and Testing of Materials and Products
(SOP 1-1)

Purpose: The purpose of this document is to establish the procedures and minimum requirements for the acceptance, verification, and certification of materials and products used on Tennessee Department of Transportation (TDOT) projects and projects under the oversight of TDOT (Local Projects, Grants, etc. that include Federal Funds).

Background: Federal Law (23 CFR 637) requires each state develop a quality assurance program which assures all materials, on projects where Federal Funds are used, conform to the requirements of the approved plans and specifications. In addition, these procedures assure projects using state funds will also be constructed using approved materials.

Policy: All materials used on TDOT projects must be accepted prior to use. Acceptance of materials is by:

A. Testing before product placement (e.g. hot mix asphalt, Portland cement concrete, base materials).

B. Manufacturers’ certifications followed by random verification testing (e.g. reinforcing steel, cement, liquid asphalt).

C. Pre-approval and testing of a product or its components (e.g. aggregate quality, gray iron castings, reinforced concrete pipe, corrugated metal pipe).

D. The Qualified Products List (QPL) with certifications (e.g. sign sheeting, erosion control blankets, pavement marking materials).

Sampling and Testing Materials and Products

1. Test Types

There are three basic types of sampling and tests routinely conducted: acceptance, verification, and assurance. All testing shall be performed by a certified technician.

1.1 Acceptance Sampling and Testing

These tests are conducted to approve or accept a product, or combination of materials (systems), by comparing the test results to specification requirements. Acceptance tests are based on a lot or frequency, during the production and/or placement of that product,
to ensure specification compliance. There are products that are sampled, tested, and accepted at the manufacturer’s facility and then delivered to TDOT projects for use.

1.2 Verification Sampling and Testing

These tests are conducted to verify/validate that products accepted by manufacturers’ certifications are in compliance with the applicable Tennessee Department of Transportation Standard Specifications for Road and Bridge Construction January 1, 2015 (Standard Specifications). In accordance with Federal Law (23 CFR 637), “The verification sampling shall be performed on samples that are taken independently of the quality control samples.”

1.3 Independent Assurance Sampling and Testing

These are tests conducted to assure that acceptance sampling and testing procedures are done in accordance with the specified procedures and to compare testing equipment.

2. Material Certifications

2.1 All materials accepted on certification must have a Material Certification and/or Sampling Testing Record DT-0044 (T-2) form, completed by the Contractor, showing contract number, project number, county, item number, quantity of material being accepted, etc. Attach the T-2 form to the manufacturer's certification and forward to the Regional Materials and Tests (M&T) Supervisor. The Manufacturer’s certification shall state that materials have been tested and inspected and that the manufacturer certifies that TDOT requirements (specifications) have been met. The Manufacturer’s certification shall contain at a minimum the manufacturer’s name, contact information, and specifications that the material meets.

2.2 The manufacturer's certification may not be project specific (i.e. it will not have the contract or project number on the certification). When this occurs, do not write the contract or project number on the certification. Instead, require the contractor to complete, and have notarized, a T-2 form, and attach the manufacturer’s certification. Copies of certifications will be acceptable provided originals are kept on file by the contractor, supplier, or manufacturer and available for inspection.

2.3 Any material that is on the Department's QPL may be accepted by a certification from the manufacturer stating that the material furnished to the project is the same as the material evaluated for the QPL. The Contractor shall forward the certification and a T-2 form to the Project Supervisor for review.

2.4 It is the project personnel's responsibility to provide the final inspection on all material. If for any reason the material is suspect, it should not be used until further evaluation is conducted. Contact the Regional M&T Supervisor for further evaluation(s).

2.5 All manufacturers' certifications must be signed; however, for seed, sod, and nursery materials, the Tennessee Department of Agriculture will provide the certification. Any certification that is not project specific shall be notarized.
2.6 Miscellaneous materials used on special projects (e.g. rest areas) that are overseen by an architect or consulting engineer for the Architecture Department may be accepted by a blanket certification stating that all materials meet specification requirements.

2.7 Material (e.g. tack) transfer shall be completed by the contractor and sent to the Project Supervisor(s) overseeing the projects. The project office(s) will verify that the quantity of material is available for transfer. The contractor shall complete the T-2 form and transfer request with all of the project information needed including applicable bill of lading and the material certification.

2.8 At completion of the project, the Project Supervisor must submit a signed Materials and Tests Certification (DT-1696) form to Regional Operations and the Regional M&T Supervisor(s). The form shall then be forwarded to the Headquarters (HQ) M&T.

2.9 The Contractor shall forward ALL certifications and T-2 forms to the Project Supervisor for review. The Project Supervisor will forward to Regional M&T for review and copies will be forwarded to HQ M&T as necessary.

3. Buy America Certifications

All iron and steel products shall meet TDOT Special Provision 106A, “Buy America,” requirements as set forth in the contract.

4. Using the Tables

4.1 There are five parts to this procedure; each part has a specific purpose and must be checked for any material to be put in use. If field personnel are unsure as to how a material is accepted, they need to contact their Regional M&T representative for clarification to assure that acceptable material is utilized on projects.

Part 1 - Sampling and Testing Guide is a field guide that lists the materials that are accepted based off certification or QPL listing, by acceptance tests, and/or verification tests.

Part 2 - Acceptance Sampling and Testing Schedule lists construction materials, test(s) to be performed, who takes the sample, how frequently a sample is taken, and where to take the sample.

Part 3 - Verification Sampling and Testing Schedule gives the details for Verification Test requirements. All verification samples must be submitted for testing within two weeks of the sample date.

Part 4 - Using Random Numbers for Sampling and Testing will help personnel choose random and representative test locations when performing tests using random number tables, calculators, spreadsheet program, etc.

Any reference to sampling by M&T refers to TDOT Regional M&T, and HQ M&T refers to TDOT Headquarters M&T.
4.3 Project Inspector references TDOT personnel performing project inspection or, for projects that include Federal Funds constructed under the oversight of TDOT (Local Programs, Grants, etc.), the Agency’s Construction Engineering Inspection (CEI) or certified sampling and testing technician assigned by the Department.

4.4 All samples should be taken at random test locations (see Part 4).

5. Useful Links

5.1. M&T Forms

All required DT Forms mentioned in Part 1 can be found here.

5.2. QPL

Materials with a QPL requirement as shown in Part 1 are listed here along with all requirements a product must meet to be on the QPL.

5.3. Producer List

Producers of these materials must be approved prior to use. All requirements to be on the Producer List are available at the link provided.

5.4. TDOT Specifications & Special Provisions
<table>
<thead>
<tr>
<th>Material Information</th>
<th>Cert. (X) or QPL T-2 Req.</th>
<th>Accept (Part 2)</th>
<th>Verify (Part 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AGGREGATE PRODUCTS</strong>&lt;br&gt;&lt;br&gt;<strong>Required Paperwork:</strong>&lt;br&gt;Project Inspector is responsible for requesting a Fine and Coarse Aggregate Inspection Report (DT-0275) form from Regional M&amp;T for each size or type of aggregate before material is shipped to the job site. When applicable, contact Regional M&amp;T to ensure proctors have been performed.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>General Aggregate (e.g. Underdrains) 903</strong>&lt;br&gt;Gradation testing and quality samples will be taken at a point in production which ensures that representative sampling and testing occurs.</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Rip-Rap from a Quarry: Regional M&amp;T will issue test reports for quality and quantity only. The Project Inspector is responsible for size at time of placement.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rip-Rap from a Job Site: The Project Inspector will notify Regional M&amp;T so that a quality sample may be obtained and a Coarse Aggregate Quality Report (DT-0320) form issued. The Project Inspector will be responsible for size at time of placement.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Aggregate-Cement Base: 309</strong>&lt;br&gt;&lt;br&gt;<strong>Additional Paperwork:</strong>&lt;br&gt;Project Inspector will complete a Daily Report on Soil and Aggregate Stabilization (DT-0298) form.</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Aggregate - Lime - Fly Ash Stabilized Base: 312</strong>&lt;br&gt;&lt;br&gt;<strong>Additional Paperwork:</strong>&lt;br&gt;Project Inspector will complete a Daily Report on Aggregate-Fly Ash Stabilization (DT-1411) form.</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Granular Backfill: 204.06</strong>&lt;br&gt;&lt;br&gt;<strong>Additional Paperwork:</strong>&lt;br&gt;Project Inspector will complete a Density Worksheet – Nuclear Method (DT-0314) form.</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Mineral Aggregate Base: 303</strong>&lt;br&gt;&lt;br&gt;<strong>Additional Paperwork:</strong>&lt;br&gt;Project Inspector will complete a Daily Report on Mineral Aggregate Base (DT-0307) form for Type “A” and “B” bases.</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>AGRICULTURAL LIMESTONE: 918.04</strong>&lt;br&gt;&lt;br&gt;<strong>Required Paperwork:</strong>&lt;br&gt;The Contractor shall provide an invoice and documentation that the agricultural limestone meets the Department of Agriculture Tennessee Liming Materials Act.</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
### Part One: Sampling and Testing Guide

<table>
<thead>
<tr>
<th>Material Information</th>
<th>Cert. (X) or QPL T-2 Req.</th>
<th>Accept (Part 2)</th>
<th>Verify (Part 3)</th>
</tr>
</thead>
</table>

#### ASPHALT (GENERAL)
Before taking samples of asphalt cement (A.C.) and emulsion, a one-gallon minimum shall be discarded to flush the sampling pipe of possible contaminants. All precautions must be taken to avoid sample contamination.

<table>
<thead>
<tr>
<th>Asphalt Aggregate: 903</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Required Paperwork:</em></td>
</tr>
<tr>
<td>The TDOT Plant Inspector will complete the Daily Report from the workbook.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Asphalt Cement: 904.01</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Required Paperwork:</em></td>
</tr>
<tr>
<td>Each shipment from the asphalt terminal shall be accompanied by a completed (DT-0293 PG) form.</td>
</tr>
</tbody>
</table>

#### Terminal Samples:
Refer to SOP 3-1.

<table>
<thead>
<tr>
<th>Contract Samples:</th>
</tr>
</thead>
<tbody>
<tr>
<td>All samples from asphalt plants shall be taken from the sampling valve on storage tanks and not from transport units. Samples taken, from projects utilizing liquid anti-stripping additives (ASA), should either contain ASA or be accompanied by an ASA sample.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Asphalt Emulsion: 904.03</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Required Paperwork:</em></td>
</tr>
<tr>
<td>Each shipment from the asphalt terminal shall be accompanied by a completed (DT-0293 Emulsion) form.</td>
</tr>
</tbody>
</table>

#### Terminal Samples:
Refer to SOP 3-2.

<table>
<thead>
<tr>
<th>Contract Samples:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refer to <a href="https://example.com">Sampling Asphalt Emulsions (pdf)</a> and <a href="https://example.com">Sampling Asphalt Emulsions (pptx)</a> for detailed sampling guidance. Field samples of emulsion shall be taken from sample valves, not distributor spray bars.</td>
</tr>
</tbody>
</table>

For field samples, sieve test results < 0.3 will be considered passing. Field samples with sieve results > 0.3 will be evaluated on a case by case basis by the Regional M&T Supervisor and the State Bituminous Engineer to determine if the sample passes or fails. For failing sieve test results, the Project Supervisor shall make a note as to whether or not an acceptable uniform spread was achieved.

<table>
<thead>
<tr>
<th>Asphalt Mix: 407</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Required Paperwork:</em></td>
</tr>
<tr>
<td>When required, the Project Inspector will complete a Daily Asphalt Density Report (DT-0315) form.</td>
</tr>
</tbody>
</table>
## Part One: Sampling and Testing Guide

<table>
<thead>
<tr>
<th>Material Information</th>
<th>Cert. (X) or QPL T-2 Req.</th>
<th>Accept (Part 2)</th>
<th>Verify (Part 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BOLT AND NUT ASSEMBLIES FOR HIGH STRENGTH STEEL STRUCTURES: 908.04</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The manufacturer/distributor shall furnish, for each heat number and/or assembly lot number, a mill test report, and/or a manufacturer/distributor certified test report. TDOT will issue a lab serial number for each manufacturer/distributor submittal.</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Additional Paperwork:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shipments to the project shall be accompanied by a copy of the TDOT lab serial number identifying each heat.lot number.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BRICK (CLAY OR SHALE, CONCRETE, SEWER): 912</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Additional Paperwork:</strong></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>All brick shall be certified with test reports by the manufacturer stating that specification requirements are met. The Contractor shall submit the certifications and list the type of brick on T-2 form.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BRIDGE DECK SEALS (MEMBRANES): 906.01</strong></td>
<td></td>
<td>QPL 2</td>
<td></td>
</tr>
<tr>
<td><strong>BRIDGE PAINT</strong></td>
<td></td>
<td>QPL 3</td>
<td>X</td>
</tr>
<tr>
<td><strong>CALCIUM CHLORIDE: 921.02</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CONCRETE (GENERAL)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Required Paperwork:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Project Inspector will complete the Concrete Cylinder Test Report (DT-0062) form for each set of cylinders.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cylinders made for Class CP concrete shall be two (2) 6”x12” cylinders. Cylinders for all other concrete shall be two (2) 4”x8” cylinders. Perform all field tests using the same sample. Refer to SOP 4-4 for submittal and approval of concrete mixtures.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Aggregate: 903.01 &amp; 903.03</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Additional Paperwork:</strong></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>The Project Inspector will check the Contractor’s Daily Report of Concrete Inspection (DT-0311) form that is completed by the contractor's certified Concrete Field Testing Technician to ensure that gradation, wash, and Fineness Modulus (FM) requirements are met and tests are performed in accordance with the approved process control plan.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cast in Place (e.g. drainage structures)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Additional Paperwork:</strong></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>The contractor shall provide a Contractor’s Daily Report of Concrete Inspection (DT-0311) form and a T-2 form that includes: each structure item number, type of structure, Standard Drawing Number, and the code number per structure. Contractor certification(s), stating that the item number was constructed in accordance with the Standard Drawing(s) and specifications, and mill certification(s) shall be attached.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cubic yards of concrete and reinforcing steel shall be identified per structure as incidental items.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material Information</td>
<td>Cert. (X) or QPL T-2 Req.</td>
<td>Accept (Part 2)</td>
<td>Verify (Part 3)</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------------</td>
<td>---------------------------</td>
<td>----------------</td>
<td>-----------------</td>
</tr>
<tr>
<td><strong>Cement, Fly Ash, &amp; Ground Granulated Blast Furnace Slag: 901.01, 921.15, &amp; 921.16</strong></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><strong>Chemical Admixture: 921.06</strong></td>
<td>QPL 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Closure Pour</strong></td>
<td>QPL 43</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Coatings, Curing Compounds (White or Clear): 604.21 &amp; 913.05</strong></td>
<td>QPL 12</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Flowable Fill: 204.06</strong></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><em>Additional Paperwork:</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The producer shall furnish a Contractor’s Daily Report of Concrete Inspection (DT-0311) form per day’s production.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Grout: 921.09</strong></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><em>Additional Paperwork:</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The producer shall furnish a Contractor’s Daily Report of Concrete Inspection (DT-0311) form per day’s production.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Non-Structural Grout</strong></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>The producer will furnish a mix design to the Project Supervisor. The mix design will be reviewed and approved by Regional M&amp;T.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Structural Grout</strong></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>If the grout has a strength requirement, a mix design shall be submitted to HQ M&amp;T.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pre-Packaged Mix</strong></td>
<td>QPL 13</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Precast Products: SOP 5-3</strong></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Prestressed Products: 615, SOP 5-4</strong></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Ready Mix: 501 &amp; 604</strong></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><em>Additional Paperwork:</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The producer shall furnish a Contractor’s Daily Report of Concrete Inspection (DT-0311) form per day’s production.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Part One: Sampling and Testing Guide

<table>
<thead>
<tr>
<th>Material Information</th>
<th>Cert. (X) or QPL T-2 Req</th>
<th>Accept (Part 2)</th>
<th>Verify (Part 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CORRUGATED METAL PIPE (CMP): 915.02</strong></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><em>Required Paperwork:</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Certified mill test report and galvanization report shall accompany sample.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Approved pipe will be stenciled “TDOT” and reported on Inspection of Corrugated Metal Pipe (DT-0280) form by Regional M&amp;T.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>The Producer shall notify the Regional M&amp;T prior to shipping.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>EARTH RETAINING STRUCTURES: SP 624</strong></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>ELECTRICAL ITEMS/ITS COMPONENTS/LIGHTING/TRAFFIC SIGNALS: 730</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Additional Paperwork:</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Contractor shall submit a certificate of compliance and certifications stating that all materials meet TDOT specifications with a T-2 form including all final quantities. In addition, the Contractor shall also provide an approval letter from the owner/maintaining agency stating acceptance of the completed system.</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For temporary traffic signal systems, the Contractor shall furnish certifications stating that all materials furnished meet Standard Specifications.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>EROSION CONTROL ITEMS: 209</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>FENCING MATERIALS: 909</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><em>Additional Paperwork:</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Contractor shall furnish certifications citing all applicable ASTM or AASHTO Specifications.</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>FIBER EXPANSION JOINT MATERIALS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>FLEXIBLE SURFACE &amp; GROUND MOUNTED DELINEATOR POST</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>GEOTEXTILES: 740, 921.12</strong></td>
<td>QPL 36</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Each unique geotextile shall be marked with a legible print showing, as a minimum, the manufacturing plant (or manufacturing plant ID code numbers). This marking shall be located on the roll edge of the product at a frequency of once per 5 meters (16.4 feet). The marking shall be unique for each manufacturer and manufacturing plant facility.</td>
<td>QPL 36</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>QPL 17</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>QPL 5</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>QPL 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>QPL 36</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Material Information</td>
<td>Cert. (X) or QPL T-2 Req.</td>
<td>Accept (Part 2)</td>
<td>Verify (Part 3)</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------------------</td>
<td>----------------</td>
<td>----------------</td>
</tr>
</tbody>
</table>
| **GRAY IRON CASTINGS: 908.07**  
*Additional Paperwork:*  
The manufacturer shall provide notarized certification(s) of material, including quantity, item, weight, and heat date, signed by the manufacturer stating compliance with Standard Specifications and Standard Drawings.  
Castings to be incorporated into the work shall be accompanied with a certified mill test report that includes: the heat number or ID, description of the casting (including TDOT Standard Drawing Number), the weight of each casting, and the number cast from each ID. All castings shall have a traceable ID number cast into the product. | X | X | X |
| **GUARDRAIL, POSTS, BLOCKS, BOLTS, WASHERS, ETC**  
Refer to SOP 6-1 *(Procedures and Qualifications for Guardrail Manufacturer and Supplier)* | | | |
| **GUARDRAIL END TERMINAL: 705** | QPL 34 | | |
| **HIGHWAY SIGNING (PERMANENT): 713**  
The manufacturer's identification markings must be on back of each sign.  
*Additional Paperwork:*  
The Contractor shall provide mill test reports on all materials and certifications from the manufacturer showing project information and quantities.  
All sign supports shall have a certified mill test report and a galvanization report submitted. | X | OR QPL 33 | |
| **HIGHWAY SIGNING MATERIALS (REFLECTIVE SHEETING): 916** | QPL 10 | | |
| **HYDRATED LIME: 921.04** | | X | |
| **IMPACT ATTENUATOR**  
*Additional Paperwork:*  
The Contractor shall provide shop drawings and certification to the Project Supervisor for review prior to delivery. | | QPL 34 | |
| **JOINT SEALANT (NON-FIBER)** | | | QPL 5 |
# Part One: Sampling and Testing Guide

**LANDSCAPING MATERIALS**

<table>
<thead>
<tr>
<th>Material Information</th>
<th>Cert. (X) or QPL T-2 Req.</th>
<th>Accept (Part 2)</th>
<th>Verify (Part 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Commercial Fertilizer: 918.02</strong></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Additional Paperwork:</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Contractor shall provide invoices.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hay, Straw (baled plant material)</strong></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Additional Paperwork:</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>If shipped from an Imported Fire Ant (IFA) quarantine area in Tennessee, shall be accompanied by a permit from the Tennessee Department of Agriculture or other appropriate regulatory agency; the permit must state the location from which the materials originated and that the material has been inspected and found to be free of IFA.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A permit is not required when shipping these materials from a non-quarantine area. The Tennessee Department of Agriculture website has county-by-county information of quarantine areas.</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Seed, Grass: 918.01</strong></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Additional Paperwork:</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Contractor shall provide a Report on Sample of Grass Seed and Grass Seed Certification (DT-0333) form from the producer.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Each bag will be labeled in accordance with Section 43-10-106 of the Tennessee Seed Law of 1986.</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sod: 803</strong></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Additional Paperwork:</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Contractor shall provide a copy of the Department of Agriculture authorization prior to removing the sod. Nursery certificates do not indicate that sod is certified.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Trees and Shrubs: 802.02</strong></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Additional Paperwork:</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before performing any work, the Contractor shall provide a nursery dealer’s certificate with each shipment of plants. When the project is complete, the Contractor shall submit certifications.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Part One: Sampling and Testing Guide

<table>
<thead>
<tr>
<th>Material Information</th>
<th>Cert. (X) or QPL T-2 Req.</th>
<th>Accept (Part 2)</th>
<th>Verify (Part 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PAVEMENT MARKERS (RAISED &amp; SNOWPLOWABLE), THERMOPLASTIC ALTERNATES, PREFORMED TAPE: 716</strong></td>
<td>QPL 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PAVEMENT MARKINGS (PAINT, THERMOPLASTIC, &amp; BEADS): 716</strong></td>
<td>X</td>
<td>OR</td>
<td>X</td>
</tr>
<tr>
<td>Additional Paperwork: The Contractor shall provide a Daily Pavement Marking (DT-1296) form on the marking materials/ beads used. The Project Inspector will verify quantities and thicknesses, sign the daily form, and submit the form to the Regional M&amp;T office weekly. At completion, the marking contractor shall provide a T-2 form listing quantities of marking materials and beads used for each pay item, colors’ batch numbers, and lab serial numbers used on the project.</td>
<td>X</td>
<td>QPL 1</td>
<td></td>
</tr>
<tr>
<td>Samples shall be submitted to HQ M&amp;T by the manufacturer to obtain lab serial numbers.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PVC / HDPE / SRTRP / PP PIPE: 914</strong></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional Paperwork: The Contractor shall provide certifications of compliance from the producer or manufacturer of all plastic pipe and tubing.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SOIL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Required Paperwork: Project Inspector will submit a Proctor Density Report (DT-0332) form along with the sample. Densities shall be reported on Density Worksheet – Nuclear Method (DT-0314) form.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Embankment &amp; Subgrade: 205, 207</strong></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Soil-Lime Subgrade Treatment: 302</strong></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Soil-Cement Base: 304</strong></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>STEEL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assembly to be in accordance with project drawings.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dowel &amp; Tie Bars: 907.02</strong></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Steel Reinforcement (black bar &amp; epoxy coated): 907.01</strong></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional Paperwork: Each shipment shall consist of a certified mill test report including size and heat number of the bars furnished along with a report listing contract number, size, heat number, and quantity of bar. For epoxy coated bar, an additional certificate of compliance for the coating along with a daily coating manufacturing worksheet is required.</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Part One: Sampling and Testing Guide

<table>
<thead>
<tr>
<th>Material Information</th>
<th>Cert. (X) or QPL T-2 Req.</th>
<th>Accept (Part 2)</th>
<th>Verify (Part 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Steel Structures: 908.01</strong>&lt;br&gt;Additional Paperwork:&lt;br&gt;All steel structure items (lump sum) shall have Structural Steel Shop Inspection Reports approved by TDOT Structures Division. The item numbers on the report must match the item numbers on the steel at the project site.</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Welded Wire Mesh (precast): 907.03</strong>&lt;br&gt;Additional Paperwork:&lt;br&gt;The Contractor shall provide a certified mill test report. Additional certification and independent lab results are required for drawn down wire.</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Strands (prestressed): 907.04</strong>&lt;br&gt;Additional Paperwork:&lt;br&gt;Each shipment must have stress/strain curves and manufacturer’s certification. Each reel or pack must have identification tags showing size, grade, and reel number.</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Structural Steel (pipe endwalls, catch basins, bridge repair items, etc): 908.01</strong>&lt;br&gt;Additional Paperwork:&lt;br&gt;Each shipment shall consist of a certified mill test report and a notarized certification of material signed by the manufacturer stating compliance with Standard Specifications and Standard Drawings including the following: contract number, contractor, shop order number, location of use, drawing number, quantity, item, type of steel, heat number, and manufacturer. If applicable, paint batch certifications and galvanization reports shall be included.&lt;br&gt;The Project Inspector will check the dimensions when steel is delivered to the project site.</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Structural Steel Piles: 908.15</strong>&lt;br&gt;Additional Paperwork:&lt;br&gt;Steel piles shall be accompanied by certified mill test reports showing correct heat numbers and a T-2 form including correct quantities and heat numbers used. The T-2 form and mill test report will be checked for accuracy. If the mill test report is not job specific, then the Contractor shall include documentation showing the purchase of the piling.</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Structural Steel Pile Tips</strong>&lt;br&gt;Additional Paperwork:&lt;br&gt;Steel pile tips shall be accompanied by certified mill test reports showing correct heat numbers.</td>
<td>QPL 28</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TEMPORARY TRAFFIC CONTROL ITEMS: 712

**Additional Paperwork:**
The Contractor shall submit all certifications/acceptance letters stating that all products used meet the TDOT specifications and comply with NCHRP 350 criteria. If selected from the QPL, the Contractor/Supplier shall certify that products furnished are identical to the product evaluated for the QPL.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cert. (X) or QPL T-2 Req.</th>
<th>Accept (Part 2)</th>
<th>Verify (Part 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barricades</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cones</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delineators</td>
<td>QPL 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexible Drums</td>
<td>QPL 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground Mounted Sign Supports: 916</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longitudinal Channelizing Barriers and Barricades</td>
<td>QPL 34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portable Barrier Rail</td>
<td>QPL 34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portable Sign Stands</td>
<td>QPL 33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signs</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temporary Pavement Marking Material</td>
<td>QPL 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trailer Mounted Devices (changeable message signs, flashing arrow boards)</td>
<td>QPL 29 OR QPL 30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truck Mounted and Portable Impact Attenuators</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical Panels</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### WATER, SEWER, AND OTHER UTILITY ITEMS

All utility items shall be accepted in accordance with the TDOT Construction Circular Letter 105.07-04, Utility Diaries and Inspection Procedures, or as required in other Contract documents. The utility representative shall complete the proper forms and submit to the Project Supervisor.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cert. (X) or QPL T-2 Req.</th>
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<th>Verify (Part 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WATER STOPS: 604.26 &amp; 921.08</td>
<td>X</td>
<td></td>
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</tr>
</tbody>
</table>

**Additional Paperwork:**
The Contractor shall provide a certified test report.

The Project Inspector will check all shipments for inspection tags.

### WOOD TIMBERS AND POSTS (TREATED): 911

**Additional Paperwork:**
The Contractor shall provide treatment reports and inspection reports on all wood timber and posts.
## Part Two: Acceptance Samples and Tests

<table>
<thead>
<tr>
<th>Type of Construction</th>
<th>Material</th>
<th>Test</th>
<th>Sampled By</th>
<th>Frequency</th>
<th>Location or Time of Sampling</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AGGREGATE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate for Underdrains</td>
<td>Aggregate</td>
<td>Gradation</td>
<td>M&amp;T</td>
<td>Per month</td>
<td>Project site or plant stockpile</td>
<td></td>
</tr>
<tr>
<td>Base Courses (Aggregate-Cement OR Aggregate-Lime-Fly Ash)</td>
<td>Aggregate</td>
<td>Gradation</td>
<td>Project Inspector</td>
<td>Every 2,500 tons or two per day</td>
<td>Plant stockpile</td>
<td>First sample should be taken at beginning of day.</td>
</tr>
<tr>
<td></td>
<td>Aggregate-Cement Mixture</td>
<td>Density, Moisture</td>
<td></td>
<td>Five tests per 10,000 square-yard lot</td>
<td>Immediately following compaction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aggregate-Lime-Fly Ash Mixture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Granular Backfill</td>
<td>Aggregate for Bridges, Box Culverts, &amp; other major structures</td>
<td>Gradation, Moisture</td>
<td>Project Inspector</td>
<td>Per day</td>
<td>Plant or roadway</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aggregate for Pipe Culverts</td>
<td>Gradation, Moisture</td>
<td></td>
<td>Three tests per layer</td>
<td>Immediately following compaction</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral Aggregate Base</td>
<td>Mineral Aggregate</td>
<td>Proctor, Specific Gravity, Optimum Moisture</td>
<td>M&amp;T</td>
<td>Per year or as material changes</td>
<td>At source</td>
<td>Quality report required for each project.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aggregate</td>
<td>Gradation, Moisture</td>
<td>Project Inspector</td>
<td>At beginning of project and every 2500 tons thereafter (Minimum of 1 per week)</td>
<td>Plant or roadway</td>
<td>First sample should be taken at beginning of day.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Density, Moisture</td>
<td></td>
<td>Three tests per layer</td>
<td>Immediately following compaction</td>
<td></td>
</tr>
<tr>
<td>Small Quantities</td>
<td>Gradation</td>
<td>Per day</td>
<td></td>
<td>Five tests per 10,000 square-yard lot</td>
<td>Immediately following compaction</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Per layer every 50 feet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ASPHALT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asphalt Plant Mix Pavements</td>
<td>Aggregate</td>
<td>Fractured Face Count</td>
<td>Project Inspector</td>
<td>Per project</td>
<td>Coarse aggregate stockpiles</td>
<td>Plus No. 4 (4.75 mm) sieve material, gravel mixes only.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Glassy Particles by mass</td>
<td></td>
<td></td>
<td></td>
<td>Plus No. 4 (4.75 mm) sieve material, slag mixes only.</td>
</tr>
<tr>
<td>All Plant Mix Asphalt</td>
<td>Mix Temperature</td>
<td></td>
<td></td>
<td>Every 5th load</td>
<td>From the truck prior to leaving the plant and on the roadway prior to deposit into the paver or the material transfer device</td>
<td>Temperatures on the roadway are to be recorded on the delivery ticket.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 Minute Boil Test</td>
<td></td>
<td>Per day</td>
<td>From the truck at the asphalt plant</td>
<td></td>
</tr>
<tr>
<td>Plant Mix Asphalt (Grading A, B, BM, BM2, C, CW, D, E, E-Shoulder)</td>
<td>Density</td>
<td></td>
<td></td>
<td>Every 1,000 tons</td>
<td>As soon as practical after compaction</td>
<td>Each lot shall be divided into 5 equal sub-lots, and one test shall be performed per sub-lot.</td>
</tr>
<tr>
<td>Plant Mix Asphalt (Grading B, BM, BM2, C, CS, CW, D, E, TL, TLD, TLE, and OGFC)</td>
<td>Loss On Ignition (Surface Mix Only)</td>
<td></td>
<td></td>
<td>Per day</td>
<td>Completed mix in truck</td>
<td>LOI testing is to be run on the extracted aggregate reclaimed from the completed plant mix.</td>
</tr>
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<td></td>
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<td>If daily sample fails, take 3 cores per lot placed that day to determine LOI.</td>
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<td></td>
<td></td>
<td>Asphalt Content: AASHTO T-164, Method E-II by extraction, or AASHTO T-308 by ignition oven.</td>
<td></td>
<td>Every 1,000 tons</td>
<td>If testing completed mix, perform extraction using AASHTO T-164 Method E-II utilizing nested sieves (No. 16 and No. 200).</td>
<td>AASHTO T-164 Method A may be used for modified asphalt or when problems are encountered filtering according to Method E-II.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aggregate Gradation: AASHTO T-30 and AASHTO T-11</td>
<td></td>
<td></td>
<td></td>
<td>Not required on production days of less than 100 tons. Ignition oven may be utilized to determine gradation.</td>
</tr>
</tbody>
</table>
## Part Two: Acceptance Samples and Tests

<table>
<thead>
<tr>
<th>Type of Construction</th>
<th>Material</th>
<th>Test</th>
<th>Sampled By</th>
<th>Frequency</th>
<th>Location or Time of Sampling</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ASPHALT</strong></td>
<td></td>
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</tr>
<tr>
<td>Asphalt Plant Mix Pavements</td>
<td>Plant Mix Asphalt (Grading A, AS, ACRL, and Asphalt Treated Permeable Base)</td>
<td>Aggregate</td>
<td>Project Inspector</td>
<td>Every 1,000 tons</td>
<td>Combined RAP and aggregate</td>
<td>If testing completed mix, perform extraction using AASHTO T-164 Method E-II utilizing nested sieves (No. 16 and No. 200). AASHTO T-164 Method A may be used for modified asphalt or when problems are encountered filtering according to Method E-II. Not required on production days of less than 100 tons. Ignition oven may be utilized to determine gradation.</td>
</tr>
<tr>
<td>Small Quantities</td>
<td>Visual Inspection</td>
<td>Not to exceed 1,000 tons of each mix type</td>
<td>Placement site</td>
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<tr>
<td><strong>CONCRETE</strong></td>
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</tr>
<tr>
<td>Ready Mix, Closure Pour, Grout, Pre-Packaged Mix, Flowable Fill, Prestressed, &amp; Precast</td>
<td>Non-Critical Structures</td>
<td>Cylinders (28-day), Slump, Air Content, &amp; Mix Temperature</td>
<td>Project Inspector</td>
<td>Every 25 cubic yards or less weekly</td>
<td>Placement site</td>
<td>Refer to Standard Specification 604.03.</td>
</tr>
<tr>
<td>Class A, A Paving, S, X</td>
<td>Complete set of tests shall be performed on the initial load for informational purposes, not for acceptance.</td>
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<tr>
<td>Class CP</td>
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</tr>
<tr>
<td>Class D, DS, L</td>
<td>Cylinders (28-day), Slump, Air Content, &amp; Mix Temperature</td>
<td>Test first three loads and every 50 cubic yards thereafter per day per structure</td>
<td></td>
<td></td>
<td>Refer to SOP 4-1 for acceptance of concrete for bridge decks.</td>
<td></td>
</tr>
<tr>
<td>Class SCC, SH, SCC</td>
<td>Cylinders (28-day), Slumpflow, Air Content, Mix Temperature, Passing Ability by J-Ring, VSI, &amp; T-50</td>
<td>One pair of cylinders shall be cast from one of the first three passing loads.</td>
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<td></td>
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</tr>
<tr>
<td>Closure Pour Mix</td>
<td>Cylinders (28-day)</td>
<td>Beginning, middle, and end of the pour</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Structural Grout Pre-packaged Mix</td>
<td></td>
<td>Per day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flowable Fill</td>
<td>Slumpflow, Mix Temperature, &amp; Cylinders (28-day)</td>
<td>Every 100 cubic yards placed per day per use</td>
<td></td>
<td></td>
<td>Cylinders required for excavatable only.</td>
<td></td>
</tr>
<tr>
<td>Prestressed Completed Mix</td>
<td>Slump, Air Content, and Mix Temperature M&amp;T or Contractor monitored by TDOT personnel</td>
<td>Per pour</td>
<td>Prestress plant</td>
<td></td>
<td></td>
<td>Perform additional tests when slump change is apparent or as directed. One pair of backup cylinders shall be made.</td>
</tr>
<tr>
<td>Prestressed Products</td>
<td>Visual Inspection M&amp;T</td>
<td>After casting and before shipment</td>
<td></td>
<td></td>
<td></td>
<td>Each item shall be inspected after delivery to the project for cracks, spalls and/or appearance by project personnel prior to incorporating product into the project.</td>
</tr>
</tbody>
</table>

Acceptance by Certification in accordance with SOP 5-3
### Part Two: Acceptance Samples and Tests

<table>
<thead>
<tr>
<th>Type of Construction</th>
<th>Material</th>
<th>Test</th>
<th>Sampled By</th>
<th>Frequency</th>
<th>Location or Time of Sampling</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EARTH RETAINING STRUCTURES</strong></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Earth Retaining Structures</td>
<td>Backfill</td>
<td>Density</td>
<td>Project Inspector</td>
<td>Every 500 tons</td>
<td>Project site</td>
<td></td>
</tr>
<tr>
<td>Select Granular Backfill</td>
<td></td>
<td>Quality, pH, and Internal angle of friction</td>
<td>M&amp;T</td>
<td>At beginning of project and every six months thereafter</td>
<td>Aggregate plant</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electro-Chemical Analysis</td>
<td>Producer</td>
<td>At beginning of project and every 2 years thereafter</td>
<td></td>
<td>Additional test required with appearance change.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gradation</td>
<td>M&amp;T</td>
<td>At beginning of project</td>
<td>Aggregate plant or roadway</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Project Inspector</td>
<td>Every 1,000 tons (Minimum of one per week)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Finished Product</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Accept in accordance with SOP 5-3 and Special Provision 624 Retaining Walls</td>
</tr>
<tr>
<td><strong>EMBANKMENT/SUBGRADE</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Embankment</td>
<td>Soil</td>
<td>Proctor Density &amp; Optimum Moisture</td>
<td>Project Inspector</td>
<td>As required by material changes</td>
<td>Cuts sampled prior to construction. Borrow pits sampled as required prior to placement.</td>
<td>Submit 50-75 pound sample to M&amp;T.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Density, Moisture</td>
<td></td>
<td>Five tests each 10 inches of lift not to exceed 1,500 feet of roadway or 5,000 cubic yards</td>
<td>During construction, immediately after compaction.</td>
<td>Density tests will not be required for embankment containing more than 50% of plus ⅜ inch sieve material.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Exception: Within 50 feet of a bridge end (deck or box), one test will be performed for each lift. The test will be performed alternately on the embankment and on the backfill material.</td>
<td></td>
</tr>
<tr>
<td>Subgrade Preparation</td>
<td>Soil</td>
<td>Proctor Density &amp; Optimum Moisture</td>
<td>Project Inspector</td>
<td>As required by material changes</td>
<td>May be sampled before grading construction or after grading prior to sub-grade preparation</td>
<td>Submit 50-75 pound sample to M&amp;T.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Density, Moisture</td>
<td></td>
<td>Five tests per 10,000 square-yard lot for top 6 inches</td>
<td>Immediately before placing pavement</td>
<td></td>
</tr>
<tr>
<td>Subgrade Treatment (Lime) OR Soil-Cement Base</td>
<td>Soil-Cement Mixture OR Soil-Lime Mixture</td>
<td>Proctor Density, Optimum Moisture</td>
<td>Project Inspector</td>
<td>Prior to beginning of construction</td>
<td>At beginning of compaction</td>
<td>Additional tests may be required to account for material changes. Submit 50-75 pound sample to M&amp;T.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pulverization</td>
<td></td>
<td>Every 10,000 square yards</td>
<td>After mixing, before compaction</td>
<td>Sieve test requirement. See Standard Specs. 304.06.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Density, Moisture</td>
<td></td>
<td>Five tests per 10,000 square-yard lot</td>
<td>Immediately following compaction</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thickness</td>
<td></td>
<td></td>
<td>After final finish of base</td>
<td></td>
</tr>
<tr>
<td><strong>MISCELLANEOUS</strong></td>
<td></td>
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</tr>
<tr>
<td>Miscellaneous</td>
<td>Corrugated Metal Pipe</td>
<td>Laboratory Analysis</td>
<td>Producer</td>
<td>Per heat number</td>
<td>Producer’s plant</td>
<td>Samples shall be submitted to HQ M&amp;T Lab prior to use.</td>
</tr>
<tr>
<td></td>
<td>Geotextiles (Type IV only)</td>
<td>Laboratory Analysis</td>
<td>Project Inspector</td>
<td>Per project</td>
<td>Project site</td>
<td>Submit a sample 100 inches in length by the width of the roll, containing at least one NTPEP manufacturing mark, to HQ M&amp;T Lab.</td>
</tr>
<tr>
<td></td>
<td>Gray Iron Castings</td>
<td>Dimensional Check</td>
<td>Project Inspector</td>
<td>Upon product placement</td>
<td>Project site</td>
<td>Check dimensions against standard drawings.</td>
</tr>
<tr>
<td>Type of Construction</td>
<td>Material</td>
<td>Test</td>
<td>Sampled By</td>
<td>Frequency</td>
<td>Location or Time of Sampling</td>
<td>Remarks</td>
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<tr>
<td><strong>AGGREGATE</strong></td>
<td></td>
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<tr>
<td>Base Courses</td>
<td>Aggregate</td>
<td>Quality</td>
<td>M&amp;T</td>
<td>Every six months</td>
<td>At source</td>
<td>Only required if blended with a recycled material.</td>
</tr>
<tr>
<td></td>
<td>Cement</td>
<td>Laboratory Analysis</td>
<td>Project Inspector</td>
<td>At beginning of project and every month thereafter</td>
<td>Mixing site</td>
<td>Mixture dosage rate should be checked.</td>
</tr>
<tr>
<td></td>
<td>Fly Ash Lime</td>
<td></td>
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</tr>
<tr>
<td>Mineral Aggregate Base</td>
<td>Aggregate</td>
<td>Quality</td>
<td>M&amp;T</td>
<td>Every six months</td>
<td>At source</td>
<td>Quality report required for each project.</td>
</tr>
<tr>
<td><strong>ASPHALT</strong></td>
<td></td>
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<tr>
<td>Asphalt Binder</td>
<td>Performance Graded Asphalt Cement</td>
<td>Laboratory Analysis</td>
<td>Contractor monitored by TDOT personnel</td>
<td>Beginning of project and weekly thereafter</td>
<td>Asphalt plant</td>
<td>One-quart sample shall be sent to HQ M&amp;T Lab.</td>
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<tr>
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<tr>
<td>Asphalt Plant Mix Pavements</td>
<td>Plant Mix Asphalt (Grading B, BM, BM2, C, CW, D, E)</td>
<td>Air Voids and Volumetric Properties: AASHTO T-166, AASHTO T-209, and AASHTO T-269</td>
<td>Project Inspector or M&amp;T</td>
<td>During Test Strip Construction or Mix Verification</td>
<td>Completed mix in truck</td>
<td>Exempt small quantities (&lt; 1,000 tons).</td>
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<tr>
<td>Asphalt Surface Treatments: Cape Sealing, Fog Sealing, Microsurfacing, Slurry Sealing, Scrub Sealing, etc.</td>
<td>Aggregate</td>
<td>Gradation</td>
<td>M&amp;T</td>
<td>At beginning of project and every week thereafter</td>
<td>Project stockpile</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Emulsion</td>
<td>Laboratory Analysis</td>
<td>Contractor monitored by TDOT personnel</td>
<td></td>
<td>Distributor truck</td>
<td>Two-quarter sample must be received at HQ M&amp;T Lab less than two weeks after sampling. Minimum of five days between samples is required.</td>
</tr>
<tr>
<td></td>
<td>Emulsion</td>
<td>Laboratory Analysis</td>
<td>Contractor monitored by TDOT personnel</td>
<td>At beginning of project and every week thereafter</td>
<td>Distributor truck</td>
<td>Two-quarter sample must be received at HQ M&amp;T Lab less than two weeks after sampling. Minimum of five days between samples is required.</td>
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<tr>
<td><strong>CONCRETE</strong></td>
<td></td>
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</tr>
<tr>
<td>Ready Mix, Closure Pour, Grout, Pre-Packaged Mix, Flowable Fill, Prestressed, &amp; Precast</td>
<td>Cement, Fly Ash, and GGBFS</td>
<td>Laboratory Analysis</td>
<td>M&amp;T</td>
<td>Every two months</td>
<td>Concrete plant</td>
<td>Eight to ten pound sample shall be sent to HQ M&amp;T Lab.</td>
</tr>
<tr>
<td></td>
<td>Aggregate: Coarse &amp; Fine</td>
<td>Quality</td>
<td></td>
<td>Every six months</td>
<td>Aggregate plant</td>
<td>Also as appearance changes or locations in quarry are changed. Additional samples to be obtained when production exceeds normal output.</td>
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<tr>
<td></td>
<td></td>
<td>Gradation and Wash (Not required for small quantities)</td>
<td></td>
<td>Per month</td>
<td>Concrete plant</td>
<td>Perform wash test on fine aggregate only when percent passing the No. 200 sieve dry exceeds 2.0%.</td>
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<tr>
<td>Precast Products</td>
<td>Verification in accordance with SOP 5-3</td>
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</tr>
<tr>
<td><strong>EARTH RETAINING STRUCTURES</strong></td>
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</tr>
<tr>
<td>Earth Retaining Structures</td>
<td>Backfill</td>
<td>Quality</td>
<td>M&amp;T</td>
<td>Every six months or every 200,000 tons</td>
<td>Aggregate plant</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gradation</td>
<td></td>
<td>At beginning of project and every month thereafter</td>
<td>Aggregate plant or roadway</td>
<td>Producer to run gradation weekly as in Quality Control Plan.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Proctor/Unit Weight</td>
<td></td>
<td>At beginning of project and every year thereafter</td>
<td></td>
<td></td>
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<tr>
<td>Finished Product</td>
<td>Verification in accordance with SOP 5-3</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Strength Absorption (Modular Block Only)</td>
<td>M&amp;T</td>
<td>Per production run</td>
<td>Producer yard (In-State)</td>
<td></td>
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<td></td>
<td></td>
<td>Project site (Out-of-State)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of Construction</td>
<td>Material</td>
<td>Test</td>
<td>Sampled By</td>
<td>Frequency</td>
<td>Location or Time of Sampling</td>
<td>Remarks</td>
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<tr>
<td><strong>EMBANKMENT/SUBGRADE</strong></td>
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</tr>
<tr>
<td>Soil - Cement Base</td>
<td>Cement</td>
<td>Laboratory Analysis</td>
<td>Project Inspector</td>
<td>Per month</td>
<td>Mixing site</td>
<td></td>
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<tr>
<td><strong>MISCELLANEOUS</strong></td>
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</tr>
<tr>
<td>Miscellaneous</td>
<td>Bolt/Nut/Washer Assemblies</td>
<td>Laboratory Analysis</td>
<td>Producer</td>
<td>Per heat number</td>
<td>Producer's plant</td>
<td>Prior to use, send a sample of three assemblies to HQ M&amp;T Lab.</td>
</tr>
<tr>
<td>Brick</td>
<td>Strength &amp; Absorption</td>
<td>Project Inspector</td>
<td>At beginning of project</td>
<td>Project site</td>
<td></td>
<td>Prior to use, send a sample of five bricks to HQ M&amp;T Lab.</td>
</tr>
<tr>
<td>Corrugated Metal Pipe</td>
<td>Dimensional Check</td>
<td>M&amp;T</td>
<td>Per pipe</td>
<td>Producer's plant</td>
<td></td>
<td>Verify length of pipe and that heat numbers match lab acceptance.</td>
</tr>
<tr>
<td>Fencing Materials</td>
<td>Laboratory Analysis</td>
<td>Project Inspector</td>
<td>At beginning of project</td>
<td>Project site</td>
<td></td>
<td>Prior to use, send a sample of three assemblies to HQ M&amp;T Lab.</td>
</tr>
<tr>
<td>Gray Iron Castings</td>
<td>Laboratory Analysis</td>
<td>M&amp;T</td>
<td>Per quarter</td>
<td>Producer's plant</td>
<td></td>
<td>Send two heat numbers (test bars) to HQ M&amp;T Lab.</td>
</tr>
<tr>
<td></td>
<td>Dimensional &amp; Weight Check</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Check one assembly representing each structure device type.</td>
</tr>
<tr>
<td><strong>PAVEMENT MARKINGS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pavement Markings</td>
<td>Glass Beads</td>
<td>Laboratory Analysis</td>
<td>Producer</td>
<td>Per lot number</td>
<td>Producer's plant</td>
<td>Prior to use, send one quart from each lot representing 44,000 pounds to HQ M&amp;T Lab.</td>
</tr>
<tr>
<td></td>
<td>Paint</td>
<td>Laboratory Analysis</td>
<td>Producer</td>
<td>Per lot number</td>
<td>Producer's plant</td>
<td>Prior to use, send one pint to HQ M&amp;T Lab.</td>
</tr>
<tr>
<td></td>
<td>Thermoplastic</td>
<td>Laboratory Analysis</td>
<td>Producer</td>
<td>Per lot number</td>
<td>Producer's plant</td>
<td>Prior to use, send one quart to HQ M&amp;T Lab.</td>
</tr>
<tr>
<td><strong>STEEL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel</td>
<td>Steel Bars</td>
<td>Laboratory Analysis</td>
<td>Producer</td>
<td>Every six months</td>
<td>Producer's plant</td>
<td>Two bars 34 inches in length shall be sent to HQ M&amp;T Lab.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M&amp;T</td>
<td>Per year</td>
<td>Producer's plant or project site</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Per inspection</td>
<td>Precast plant</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Per project</td>
<td>Prestressed plant</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Prestressing Strands</td>
<td>Producer</td>
<td>Every six months</td>
<td>Producer's plant</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M&amp;T</td>
<td>At beginning of project</td>
<td>Prestressed plant</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Welded Wire Mesh</td>
<td>Producer</td>
<td>Every six months</td>
<td>Producer's plant</td>
<td></td>
<td>A two foot by two foot sample shall be sent to HQ M&amp;T Lab.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M&amp;T</td>
<td>Per inspection</td>
<td>Precast plant</td>
<td></td>
</tr>
</tbody>
</table>
Significance

The selection of test locations is critical in ensuring control of materials and construction work. If the results from the test locations conform to specified tests, the rest of the work is likely to conform as well; therefore, test site locations shall be random and representative of the material in its entirety.

The procedures outlined below will help you to select random and representative test locations using random number tables, a random number function on a calculator, a spreadsheet program, etc.

Selecting Random Numbers

Randomness in transportation construction inspection indicates unpredictability in the time or location of sampling and testing of a material or procedure in a construction phase.

Random numbers occur in no pattern or sequence. When you review a series of random numbers, you do not know what number may come next; there is no particular order in which random numbers occur.

A sample random-number table is shown below.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.814</td>
<td>0.793</td>
<td>0.651</td>
<td>0.947</td>
</tr>
<tr>
<td>0.581</td>
<td>0.877</td>
<td>0.500</td>
<td>0.208</td>
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<tr>
<td>0.105</td>
<td>0.015</td>
<td>0.323</td>
<td>0.630</td>
<td>0.233</td>
</tr>
<tr>
<td>0.616</td>
<td>0.016</td>
<td>0.070</td>
<td>0.465</td>
<td></td>
</tr>
<tr>
<td>0.672</td>
<td>0.031</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.035</td>
<td>0.641</td>
<td>0.990</td>
<td>0.184</td>
<td>0.488</td>
</tr>
<tr>
<td>0.794</td>
<td>0.909</td>
<td>0.940</td>
<td>0.062</td>
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<tr>
<td>0.031</td>
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<td>0.385</td>
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<td>0.521</td>
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<td>0.278</td>
<td>0.423</td>
<td>0.365</td>
<td>0.010</td>
<td>0.210</td>
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<td>0.264</td>
<td>0.745</td>
<td>0.378</td>
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<td>0.597</td>
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<td>0.995</td>
<td>0.962</td>
<td>0.951</td>
</tr>
<tr>
<td>0.323</td>
<td>0.630</td>
<td>0.223</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.616</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>0.070</td>
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<td>0.469</td>
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</tr>
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<td>0.931</td>
<td></td>
<td></td>
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<td></td>
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<td>0.204</td>
<td>0.159</td>
<td>0.006</td>
<td>0.006</td>
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<tr>
<td>0.764</td>
<td>0.020</td>
<td>0.768</td>
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<tr>
<td>0.209</td>
<td>0.959</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>0.147</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>0.426</td>
<td>0.660</td>
<td>0.160</td>
<td>0.009</td>
<td></td>
</tr>
<tr>
<td>0.978</td>
<td>0.023</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.394</td>
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<td></td>
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<tr>
<td>0.445</td>
<td></td>
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<tr>
<td>0.650</td>
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<td></td>
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</tr>
<tr>
<td>0.600</td>
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<td></td>
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</tr>
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<td>0.590</td>
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<td>0.561</td>
<td>0.946</td>
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</tr>
<tr>
<td>0.129</td>
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<tr>
<td>0.384</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>0.363</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.038</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.275</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.837</td>
<td>0.658</td>
<td>0.423</td>
<td>0.365</td>
<td></td>
</tr>
<tr>
<td>0.010</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.210</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.264</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>0.745</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.378</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Lot sizes vary depending on the type of construction and the material. For example, a lot for earthwork construction is defined by the width and length of roadway, while concrete tests for bridge decks (slump, temperature, and air content) are determined by the volume of concrete delivered to the site.

Determine the lot size and the number of samples and tests required per lot from the Sampling and Testing (S&T) Guide and Schedule (SOP 1-1).

Knowing the type of construction and the material to be tested, use the S&T Schedule to determine the type of test and frequency of testing.
**Example 1:** Moisture and density must be measured on a lift of soil for subgrade preparation of a roadbed. The proposed roadway is 48-feet wide.

According to the Sampling and Testing Schedule (SOP 1-1, Part 2, shown below), five tests for moisture and density are required for every 10,000-square-yard lot of soil placed.

Since the project is 48 feet wide, the lot length will be, at most,

\[
\frac{10000 \text{ yd}^2 \text{ area of aggregate } \times 9 \text{ ft}^2}{48 \text{ feet wide}} = 1875 \text{ feet per lot}
\]

We decide to use 1000 linear feet of roadway as our designated lot since this is shorter than the allowable lot length of 1875 feet.

If using the random number table shown below, we randomly choose a block of numbers, say, block C2.

Using block C2, we have 10 random numbers that range between 0 and 1 carried to the thousandth decimal place. We will use these as multiplication factors to determine our test locations in the following table. The left-hand column of numbers in block C2 will be used to determine the longitudinal coordinates (length of the proposed roadway) by multiplying the lot length by the random number, then rounding to the nearest whole number. The right-hand column of numbers in block C2 will be used to determine the lateral coordinates (perpendicular to the proposed roadway) by multiplying the lot width by the random number, then rounding to the nearest whole number.
Now, we simply match the first longitudinal coordinate with the first lateral coordinate to locate the first test location. Then, we match the remainder of the longitudinal and lateral coordinates to determine the remaining 4 test locations. The figure below shows the locations of the tests on the roadbed.

**Example 2:** Nuclear gauge tests of density on 3.5 inches of Grading 307-A asphalt pavement that is 12 feet wide. The spread rate for 3.5 inches is 402.5 lbs/yd$^2$.

According to the Sampling and Testing Schedule (SOP 1-1, Part 2, shown below), five tests for density are required for every 1,000 ton lot of asphalt placed.

<table>
<thead>
<tr>
<th>Asphalt Plant Mix Pavements</th>
<th>Plant Mix Asphalt Graddings A, B, BM, BM2, C, CW, D, E, and E Shoulder</th>
<th>Density</th>
<th>Project Inspector</th>
<th>Every 1,000 tons</th>
<th>As soon as practical after compaction</th>
<th>Each lot shall be divided into 5 equal sub-lots, and one test shall be performed per sub-lot.</th>
</tr>
</thead>
</table>

---

**PLAN VIEW OF TEST AREA**

*(NOT TO SCALE)*

1 2 3 4 5

1000'

48'

978'

764'

591'

129'

47'

33'

20'

3'

---

22 22
Since the lot size is 1,000 tons, the maximum lot size will be,

\[
1,000 \text{ tons} \times 2,000 \frac{\text{lb}}{\text{ton}} = 4,969 \text{ square yards}
\]

Converting this into square feet,

\[
4,969 \text{ yd}^2 \times 9 \frac{\text{ft}^2}{\text{yd}^2} = 44,721 \text{ ft}^2
\]

Since the project is 12 feet wide, the maximum lot will be,

\[
44,721 \text{ ft}^2 \div 12 \text{ ft wide} = 3,726.8 \text{ ft}
\]

Dividing this lot into five equal sub-lots,

Using the table of random numbers shown below, we randomly choose a block of numbers, say, block D5.

Using block D5, we have 10 random numbers that range between 0 and 1 carried to the thousandth decimal place. We will use the multiplication factors in the left-hand column to determine our longitudinal test locations. Transverse locations are determined randomly with one test 12” off each edge, one test in each wheel path, and one test in the center of the lane.

The distances into each sublot,

\[
\begin{align*}
745 \text{ ft} & \times 0.353 = 263 \text{ ft} \\
745 \text{ ft} & \times 0.347 = 259 \text{ ft} \\
745 \text{ ft} & \times 0.588 = 438 \text{ ft} \\
745 \text{ ft} & \times 0.838 = 624 \text{ ft} \\
745 \text{ ft} & \times 0.665 = 495 \text{ ft}
\end{align*}
\]
If we wanted to know the total distance into the 3750’ lot for each test:

Test 1 = 263 ft
Test 2 = 745 ft + 259 ft = 1004 ft
Test 3 = 745 ft + 745 ft + 624 ft = 2114 ft
Test 4 = 745 ft + 745 ft + 745 ft + 438 ft = 2673 ft
Test 5 = 745 ft + 745 ft + 745 ft + 495 ft = 3475 ft

**Example 3**: Slump, temperature, and air content of concrete from mixing trucks delivering concrete to a bridge deck pour that is expected to use 1300 cubic yards of concrete.

According to the Sampling and Testing Schedule (SOP 1-1, Part 2, shown below), one complete set of tests for air content, slump, and temperature are required for the first three loads of concrete delivered.

One pair of cylinders must be cast from one of the three passing loads. For each additional 50 cubic yards of concrete, a pair of cylinders must be made and tests for air content, slump, and temperature must be performed.
Now we’ll use the random number tables in a different way. We must decide which loads of concrete to test. First, we’ll assume each truck is hauling 10 cubic yards of concrete. Subsequent to the first 30 cubic yards, we’ll test from truck loads by first choosing a random block of numbers from the following table. We’ll choose block A3.

The table below shows one way to determine, using the random numbers above, the truck numbers from which samples will be taken.

<table>
<thead>
<tr>
<th>SAMPLE NO.</th>
<th>DELIVERED CONCRETE (yd³)</th>
<th>TOTAL AMOUNT OF CONCRETE (yd³)</th>
<th>TOTAL LOADS OF CONCRETE (A)</th>
<th>RANDOM NO. [(Aₙ₋₁-Aₙ₋₂)x₅]+Aₙ₋₁</th>
<th>LOAD NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>10</td>
<td>1</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>20</td>
<td>2</td>
<td>NA</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>30</td>
<td>3</td>
<td>NA</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>50</td>
<td>80</td>
<td>8</td>
<td>0.492</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>130</td>
<td>13</td>
<td>0.428</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
<td>180</td>
<td>18</td>
<td>0.443</td>
<td>15</td>
</tr>
<tr>
<td>7</td>
<td>50</td>
<td>230</td>
<td>23</td>
<td>0.505</td>
<td>21</td>
</tr>
<tr>
<td>8</td>
<td>50</td>
<td>280</td>
<td>28</td>
<td>0.447</td>
<td>25</td>
</tr>
<tr>
<td>9</td>
<td>50</td>
<td>330</td>
<td>33</td>
<td>0.633</td>
<td>31</td>
</tr>
<tr>
<td>10</td>
<td>50</td>
<td>380</td>
<td>38</td>
<td>0.126</td>
<td>34</td>
</tr>
</tbody>
</table>
**Example 4:** Slump, temperature, and air content of concrete from mixing trucks delivering concrete to a structural footing that is expected to use 550 cubic yards of concrete.

According to the Sampling and Testing Schedule (SOP 1-1, Part 2, shown below), one complete set of tests for air content, slump, and temperature are required for the first load of concrete delivered each day for quality control/informational purposes. For each additional 100 cubic yards of concrete, a pair of cylinders must be made and tests for air content, slump, and temperature must be performed.

<table>
<thead>
<tr>
<th>Portland Cement Concrete (Including Prestressed, Precast, &amp; Pavement)</th>
<th>Class A, A Paving, S, X</th>
<th>Cylinders (28-day), Slump, Air Content, &amp; Mix Temperature</th>
<th>Project Inspector</th>
<th>Every 100 cubic yards placed per day per structure unless otherwise specified (i.e. Class X)</th>
<th>Placement site</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Complete set of tests shall be performed on the initial load for informational purposes, not for acceptance.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Now we’ll use the random number tables in a different way. We must decide which loads of concrete to test. First, we’ll assume each truck is hauling 10 cubic yards of concrete. Subsequent to the first 10 cubic yards, we’ll test from truck loads by first choosing a random block of numbers from the following table. We’ll choose block C1.

![Random Number Table](image)

The table below shows one way to determine, using the random numbers above, the truck numbers from which samples will be taken for acceptance.

<table>
<thead>
<tr>
<th>SAMPLE NO.</th>
<th>TOTAL AMOUNT OF CONCRETE (yd³)</th>
<th>TOTAL LOADS OF CONCRETE (A)</th>
<th>RANDOM NO. (B)</th>
<th>LOAD NUMBER [(Aᵣ-Aᵣ₋₁) x B]+Aᵣ₋₁</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-100</td>
<td>10</td>
<td>0.273</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>101-200</td>
<td>20</td>
<td>0.614</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>201-300</td>
<td>30</td>
<td>0.585</td>
<td>26</td>
</tr>
<tr>
<td>4</td>
<td>301-400</td>
<td>40</td>
<td>0.969</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>401-500</td>
<td>50</td>
<td>0.690</td>
<td>47</td>
</tr>
<tr>
<td>6</td>
<td>501-550</td>
<td>55</td>
<td>0.383</td>
<td>52</td>
</tr>
</tbody>
</table>
**Example 5**: Assume the contractor is paving 411-D mix at 132.50 lbs/square yard at 12 feet wide. How long is the average lot and sublot?

In order to find those lengths view the following table:

<table>
<thead>
<tr>
<th>Spread (lb/SY)</th>
<th>Lot Sublot</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lot</td>
<td>34000</td>
<td>22600</td>
<td>17000</td>
<td>15100</td>
<td>13600</td>
<td>12300</td>
<td>11300</td>
<td>9700</td>
<td>7900</td>
<td>6500</td>
</tr>
<tr>
<td></td>
<td>Sublot</td>
<td>6800</td>
<td>4520</td>
<td>3400</td>
<td>3020</td>
<td>2720</td>
<td>2460</td>
<td>2260</td>
<td>1940</td>
<td>1820</td>
<td>1700</td>
</tr>
<tr>
<td>154.50</td>
<td>Lot</td>
<td>29100</td>
<td>19400</td>
<td>14600</td>
<td>12900</td>
<td>11700</td>
<td>10600</td>
<td>9700</td>
<td>8300</td>
<td>7800</td>
<td>7300</td>
</tr>
<tr>
<td></td>
<td>Sublot</td>
<td>5820</td>
<td>3880</td>
<td>2920</td>
<td>2580</td>
<td>2340</td>
<td>2120</td>
<td>1940</td>
<td>1660</td>
<td>1560</td>
<td>1460</td>
</tr>
<tr>
<td>226.00</td>
<td>Lot</td>
<td>19900</td>
<td>13300</td>
<td>10000</td>
<td>8800</td>
<td>8000</td>
<td>7200</td>
<td>6600</td>
<td>5700</td>
<td>5300</td>
<td>5000</td>
</tr>
<tr>
<td></td>
<td>Sublot</td>
<td>3980</td>
<td>2660</td>
<td>2000</td>
<td>1760</td>
<td>1600</td>
<td>1440</td>
<td>1320</td>
<td>1140</td>
<td>1060</td>
<td>1000</td>
</tr>
<tr>
<td>254.25</td>
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<td>720</td>
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</table>

Find the row with the spread rate on the plans and follow it over to the column with the appropriate mat width. Where the row and column meet the lot/sublot lengths will be listed. For our example, find the row for 132.50 lbs/square yard and the column for 12 feet wide lanes. The values are **11,300 feet/2,260 feet** for the lot/sublot respectively.

**Example 6**: Assume the final lot is 500 tons. No matter how small, all lots will still require five equal sublots and five density tests. Instead of testing 500 tons five times consider combining the final two lots and halving the tonnage between the two lots. This will result in two lots of 750 tons.

You may still use the above table to find your lot and sublots. First locate the lot and sublot length for a 1000 ton lot based on the spread rate and lane width. For this example use a spread rate of 132.5 lbs/square yard at 12 feet wide.

This would yield a Standard Lot of 11,300 feet and 2,260 feet respectively but this needs to be modified based on the shorter lot.

Now that all of the givens are known, use the following equation to solve for the final lot/sublot lengths:

\[
\left(\frac{\text{Lot Tonnage}}{1,000 \text{ tons}}\right) \times (\text{Standard Lot Length, in feet}) = \text{Lot Length, in feet}
\]

\[
\left(\frac{750 \text{ tons}}{1,000 \text{ tons}}\right) \times (11,300 \text{ feet}) = 8,475 \text{ feet} \approx 8,500 \text{ feet}
\]

Once the lot length is determined for 750 tons, divide the new lot length by 5 for equal sublot lengths:

\[
\left(\frac{8500 \text{ feet}}{5 \text{ sublots}}\right) = 1,700 \text{ feet/sublot}
\]

These values are the new lot/sublot lengths. These values may be rounded to the nearest 100’ for simplicity.
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
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Tennessee Department of Transportation
Division of Materials and Tests

Field Technician Certification Requirements (SOP 1-3)

Purpose: The purpose of this document is to establish the minimum qualifications for personnel involved in the sampling and testing of materials for process control, acceptance, and assurance purposes.

Background: Federal regulations (23 CFR 637B) require that all sampling and testing used in the materials and construction acceptance process be conducted by qualified technicians.

Policy: All TDOT and Contractor Personnel must be certified in the applicable TDOT certification workshops as required in the Standard Specifications, or when otherwise required. To become certified individuals must attend the classroom instruction and presentations, successfully complete the written examination, and successfully complete the sampling and testing proficiency demonstrations.

American Concrete Institute (ACI) Concrete Field Testing Technician Grade I is acceptable in lieu of the TDOT Concrete Field Testing Technician certification with the following exception. If self-consolidating concrete (SCC) is being produced, ACI Concrete Field Testing Technician Grade I AND ACI Self-Consolidating Concrete Testing Technician will be accepted in lieu of the TDOT Concrete Field Testing Technician certification.

Certification: Upon successful completion of a certification course, every individual must complete the TDOT Technician Certification Agreement to receive their certification cards.

De-certification: TDOT will assure all individuals that are certified continue to correctly perform and conduct the sampling and testing requirements per their certification. TDOT will maintain the right to revoke certifications from individuals whom:

- Improperly perform sampling, testing, or inspection of materials or workmanship to assure its acceptance or quality,
- Improperly report or falsify, quality control, acceptance, or assurance testing data,
- Deliberately and intentionally report data that was not obtained by testing,
- Accept materials or products that are obviously of poor workmanship and non-compliant with the TDOT Specifications.

Each infraction, as listed above, will be evaluated on a case-by-case basis. TDOT will determine the appropriate disciplinary action based on the severity, intent, type, and number of infractions. Disciplinary actions may include, written warning, verbal warning, temporary or permanent de-certification, re-examination, or others.
Courses: The Materials and Tests Division website gives a full description of each certification course offered below. The Materials and Tests Division website also contains a course schedule and registration process for each certification course.

<table>
<thead>
<tr>
<th>Certification Program</th>
<th>Required for:</th>
<th>Certification Valid for:</th>
<th>Required Per Specification:</th>
<th>Description of Workshop</th>
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<td>Asphalt Level 1</td>
<td>TDOT, CEI, and Contractor paving inspectors and</td>
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<td>407.14</td>
<td>Classroom presentation and written exam.</td>
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<tr>
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<td>TDOT, Verification and Contractor Mix Designers</td>
<td>5 years</td>
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</tr>
<tr>
<td>Concrete Field Testing Technician</td>
<td>Control</td>
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<td>501.03(B) 604.03(B)</td>
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</tr>
<tr>
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Laboratory Qualification Requirements (SOP 1-4)

Purpose-
The purpose of this document is to establish the minimum qualifications for the Central Laboratory, Regional Materials and Tests Laboratories and Contractor and Material Supplier Field Laboratories used for the control, design, acceptance, verification, and/or assurance of materials and products.

Background-
Federal regulations (23 CFR 637B) require that all laboratories used in the acceptance decision process be performed by qualified laboratories.

Policy-

Regional Laboratories
Regional Materials and Tests laboratories qualifications will fall under the auspices of the AASHTO Accredited Central TDOT Laboratory. Regional Materials and Tests laboratories will be inspected annually by the Central Laboratory. During the inspection, the Central Laboratory verifies that the requirements of AASHTO R-18 are being followed. Annually, the regions lead technician testing competency will be evaluated by Central Laboratories staff through observation of the regional technician performing round robin/proficiency samples. This observation and analysis of results obtained shall ensure the technician is qualified to run tests.

Upon completion of the laboratory inspection, the Central Laboratory will complete and report findings to the Regions Management staff which shall report findings to Regional Materials and Tests laboratory management. Regional Materials and Tests laboratory management shall then respond with the proposed corrective actions to findings found to be nonconformities.

Field Laboratories
Contractor and Material Suppliers field laboratories must meet the minimum requirements specified in Section 106.06 of the Tennessee Department of Transportation Standard Specifications for Road and Bridge Construction dated January 1, 2015, and all other applicable contract provisions.

In addition to the annual hot mix asphalt plant, concrete plant, and aggregate producing plant inspections conducted by the regions, all field laboratories must be inspected by regional staff, at a minimum, every two years to meet the requirements of Federal regulations (23 CFR 637B). The Regional Materials and Tests laboratories will be responsible for conducting and qualifying the field laboratories. The Central Laboratories will serve as reference during these inspections. All test equipment will be thoroughly reviewed and checked to assure proper tolerances and operability exists.

The Independent Assurance program will also serve as a routine opportunity to inspect the field lab test equipment and compare the test results to properly calibrated equipment. As specified in SOP 1-2 (Independent Assurance Program), when comparing test results between acceptance and assurance samples, deviations exceeding the Normal Deviation Range must be reviewed.

When laboratory equipment does not perform as required, proper corrective action will be necessary, which may include the repair, replacement, or re-calibration of equipment.
The field laboratory must maintain a log of all equipment calibrations, correlations, and/or repair work. Field laboratory equipment should also be maintained in accordance with manufacturers recommendations, or as necessary. The Contractor and Material Supplier will be issued an inspection report at the completion of the laboratory inspection. The Contractor and Material Supplier must make all corrective actions and reply in writing to the Regional Materials and Tests Supervisor what actions have been taken to rectify the finding. All corrective actions and written notification must be completed within 30 days of the inspection or the laboratory will be considered non-compliant with Subsection 106.06 of the Standard Specifications. At a minimum, the field laboratory equipment that shall be inspected by the Regional Materials and Tests laboratories for laboratory qualification is:

**TYPE A FIELD LABORATORIES**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Reference</th>
<th>Requirement</th>
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<tbody>
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<td>Scales</td>
<td>106.06 AASHTO M-231</td>
<td>Accuracy within 0.1% of known weights at 5 points or more through the scale range.</td>
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<tr>
<td>Sieves and Screens</td>
<td>106.06 ASTM E11</td>
<td>Worn and torn screens need to be repaired or discarded.</td>
</tr>
<tr>
<td>Mechanical Sieve Shakers</td>
<td>106.06 AASHTO T-27, T-30</td>
<td>Approved by the Engineer</td>
</tr>
<tr>
<td>Ovens (or stove tops and hot plates when applicable)</td>
<td>SS 106.06 AASHTO Test Methods</td>
<td>Oven must maintain constant temperature of 230 (±9)°F. Stove tops and hot plates may be used to determine moisture conditions of aggregates.</td>
</tr>
<tr>
<td>Thermometers</td>
<td>106.06 ASTM E 1 ASTM E 77 ASTM E 2251</td>
<td>Thermometers should be checked against regional calibrated thermometers at 3 different temperature ranges, difference should be less than 2%.</td>
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**TYPE B FIELD LABORATORIES**

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<td>(2) Thermometers</td>
<td>106.06 ASTM E 1 ASTM E 77 ASTM E 2251</td>
<td>Thermometers should be checked against regional calibrated thermometers at 3 different temperature ranges, difference should be less than 2%. Must have a range 50 F to 400 F.</td>
</tr>
<tr>
<td>(2) Vacuum Extractors</td>
<td>106.06 AASHTO T-164 Method E-II /ASTM D2172</td>
<td>Vacuum extractor shall have a minimum bowl capacity of 100 troy ounces. Supply an adequate amount of an approved solvent from the QPL and provide storage and disposal of the waste solvent in accordance with the regulations under the Tennessee Hazardous Waste Management Act.</td>
</tr>
<tr>
<td>Or</td>
<td>(1) Vacuum Extractor and (1) ignition furnace</td>
<td>Adequate ventilation of the extractor is required see 106.06</td>
</tr>
<tr>
<td>Suspension Apparatus and Water Bath</td>
<td>106.06 AASHTO T-166</td>
<td>Approved by the Engineer to meet AASHTO T-166 requirements, water bath must be capable of maintaining a temperature of 77±1.8°F.</td>
</tr>
<tr>
<td>Maximum Theoretical Gravity (Rice) Determination</td>
<td>106.06 AASHTO T-209</td>
<td>Vacuum, with manometer or vacuum gauge, capable of maintaining 3.7 ±0.3 kPa (27.5 ± 2.5 mm Hg) of pressure for 15 (±2) minutes, mechanical shaker capable of releasing entrapped air.</td>
</tr>
<tr>
<td>LOI Muffler Furnace and Assayer’s Fire Clay Crucible with Cover</td>
<td>106.06 407.03</td>
<td>The furnace shall be capable of maintaining a constant temperature of 950°C (1742°F) for the entire 8 hr. test cycle.</td>
</tr>
<tr>
<td>Moisture Susceptibility (Root – Tunnecliff)</td>
<td>407.03 ASTM D 4867</td>
<td>Water bath capable of maintaining 140±1.8°F for 24 hrs. and 77±1.8°F. Vacuum for specimen saturation, tensile splitting head, loading device.</td>
</tr>
<tr>
<td>Hot Plates</td>
<td>AASHTO T-245</td>
<td>Capable of maintaining a temperature within a range of ± 2.8°C (5°F) of the mixing or molding temperature.</td>
</tr>
<tr>
<td>Sampling and Quartering Equipment</td>
<td>ASTM D75 AASHTO R76</td>
<td>Shall be clean of deleterious buildup.</td>
</tr>
<tr>
<td>Miscellaneous: mixing tools, bowls, beakers, pans, pycnometers, flasks, etc…</td>
<td></td>
<td>Clean of material build up, debris, cracks, excessive wear, etc…</td>
</tr>
<tr>
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<td>106.06 AASHTO T-166</td>
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</tr>
<tr>
<td>(4) 1000 ml beakers (glass/metal) (4) Glass Rods Wire Mesh screens</td>
<td>904.01 AASHTO T59 SOP 3-2</td>
<td>Testing at Contractor’s lab only required for prime coat/tack coat material stored in a drop tanker/distributor for greater than 1 week. Materials less than a week old or materials stored in a storage tank to be tested at TDOT HQ lab.</td>
</tr>
<tr>
<td>Stackable 3” Dia sieve set (no. 20 and pan) Desiccator</td>
<td>904.01 AASHTO T59 SOP 3-2</td>
<td>Testing at Contractor’s lab only required for prime coat/tack coat material stored in a drop tanker/distributor for greater than 1 week. Materials less than a week old or materials stored in a storage tank to be tested at TDOT HQ lab.</td>
</tr>
</tbody>
</table>

**Concrete Testing Equipment**
(Per Section 501, 604, and 615 of the Standard Specifications and the Sampling and Testing Schedule)

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Reference</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slump Cone</td>
<td>AASHTO T-119</td>
<td>The cone shall be 12” H, 4” D top opening, and a 8” D bottom opening, allowable tolerances ±1/8”, the top and bottom openings shall be parallel to each other, no material buildup, surfaces shall be smooth with no dents.</td>
</tr>
<tr>
<td>Air Content by the Volumetric Method (lightweight aggregate)</td>
<td>AASHTO T-196</td>
<td>The volumetric meter shall conform to those identified in T-196, bowl shall be machined smooth, and have pressure tight flanges.</td>
</tr>
<tr>
<td>Air Content by the Pressure Method</td>
<td>AASHTO T-152</td>
<td>The pressure meter shall conform to those identified in T-152.</td>
</tr>
<tr>
<td>Yield/Unit Weight</td>
<td>AASHTO T-121</td>
<td>Apparatus shall conform to T-121.</td>
</tr>
<tr>
<td>Cure Boxes/Water Baths</td>
<td>AASHTO T-23 AASHTO M-201</td>
<td>When applicable, cure boxes or water baths shall be capable of maintaining a temperature range of 60°F to 80°F in an environment that prevents moisture lost for initial curing. For final curing a temperature range of 73.5±3.5°F in an environment maintaining a relative humidity of at least 95%.</td>
</tr>
<tr>
<td>Item</td>
<td>Specification</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>---------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Mallets</td>
<td>AASHTO test methods</td>
<td>Head shall be rubber or rawhide, 1.25±0.50 lbs.</td>
</tr>
<tr>
<td>Thermometer</td>
<td>ASTM E 77</td>
<td>Shall be capable of accurately measuring within 2%</td>
</tr>
<tr>
<td>Tamping Rods</td>
<td>AASHTO test methods</td>
<td>Shall be a straight, 5/8” D, with a hemispherical tip, and at least 16” long. (4x8 concrete cylinder molds shall use 3/8” D with a 12” long rod)</td>
</tr>
<tr>
<td>Wheelbarrows/Sampling Buckets</td>
<td></td>
<td>Equipment shall be clean and free of concrete buildup.</td>
</tr>
<tr>
<td>Compression Machines (Cylindrical Concrete Specimens)</td>
<td>AASHTO T-22</td>
<td>Shall meet the requirements of AASHTO T-22 and be capable of maintaining a constant pressure loading of 35±7 psi/sec.</td>
</tr>
<tr>
<td>Compression Machines (Concrete Pipe and Manhole Sections)</td>
<td>AASHTO T-280</td>
<td>RCP- Compression machines for three edge bearing tests shall be capable of applying a uniform linear load.</td>
</tr>
</tbody>
</table>
Tennessee Department of Transportation
Division of Materials and Tests

Emulsified Asphalt Certified Supplier Requirements (SOP 3-2)

Purpose: The purpose of this document is to establish the minimum requirements for an emulsified asphalt supplier to become certified in Tennessee, and therefore provide emulsified asphalt on TDOT projects.

Policy: All Emulsified Asphalt supplied to a TDOT project must come from a certified emulsified asphalt supplier and be in compliance with TDOT Specifications (Section 904). To become certified, the supplier or manufacturer must submit a quality control plan (QCP) in resemblance with AASHTO R-26, and as modified or required in this procedure, to TDOT for approval. The supplier must also demonstrate a history of quality control data and proof of full QCP implementation. New emulsified asphalt suppliers must submit three (3) consecutive split samples for each emulsion being shipped for TDOT verification testing.

Procedure: Definitions-
The manufacturer, as further referenced in this procedure will be the last source to produce or modify the final product. The supplier will be the last source to handle the product before being shipped, and the supplier will provide the emulsion certification report with each shipment. In many instances, the manufacturer and the supplier will be one in the same. A lot will be the quantity of a single product produced during a 30 day period; if the product is stored in multiple tanks each tank will be considered a separate lot.

Laboratory-Each manufacturer and supplier must have a designated laboratory to either certify the emulsion or to conduct quality control testing. Laboratories used to certify emulsified asphalts must participate in annual AASHTO Materials Reference Laboratory (AMRL) proficiency testing for the tests listed below and submit proficiency results to the Department once available. Any laboratory that demonstrates excessive consecutive poor proficiency testing results may be asked to conduct additional extra proficiency sample testing until non-conformities are corrected.

1. AASHTO T-59, Residue by Evaporation
2. AASHTO T-59, Residue by Distillation
3. AASHTO T-59, Sieve Test
4. AASHTO T-59, 24 Hour Storage Stability Test
5. AASHTO T-59, Saybolt Viscosity
6. AASHTO T-51, Ductility Test
7. AASHTO T-49, Penetration Test

Supplier laboratories that conduct quality control testing must have equipment to perform a Saybolt-Furol viscosity test, a Sieve test, and Percent Residue by evaporation or Percent Distillate. Quality Control testing may be defined by the supplier for rapid testing. However, all Specification Compliance testing shall follow AASHTO current test methods. Personnel conducting quality control testing must be qualified; either by training from the equipment manufacturer, trained under the direct supervision of an individual who routinely completes AMRL demonstrations and
proficiency testing, or trained by other highly proficient and competent individuals with emulsified asphalt testing experience.

**Quality Control Plan (QCP)** - Each manufacturer and supplier must submit a QCP for approval. Once approved each manufacturer and supplier shall, at the beginning of each calendar year, send either a new QCP or written notification to the department that no changes will be made to the current QCP on file. The QCP shall contain the information required in resemblance with Section 9.1 and 9.2 (or as revised below) of AASHTO R-26. In addition the plan shall include the following:

- A plan view of the facility and description of storage tanks,
- A narrative description detailing how each emulsified asphalt will be blended and handled to assure a consistent product.

**Testing for Tanks**

As a minimum **quality control** testing shall be completed on every batch added to a tank. Quality Control shall be completed before the material is shipped. **Quality Control** shall consist of either the rapid viscosity, residue and sieve tests in Appendix A or AASHTO T-59 equivalent.

**Minimum Sample Size**

The minimum sample size for terminal samples shall be: 1 Gallon.

The minimum sample size for project samples shall be: 2 Quarts.

As a minimum, TDOT will require **specification compliance testing** on every lot. Testing shall include all tests in TDOT Standard and Supplemental Specifications 904.03 for each emulsified asphalt. Email certification for each lot to: tdot.emulsionmtr@tn.gov

If a tank remains idle for more than 2 weeks, it shall be tested for quality control before shipment and every 2 weeks thereafter until another batch is added to it.

Asphalt Emulsions that are used for Micro-Surfacing, Slurry Seals, Bituminous Seal Coats (chip seals) and other Specialty Applications shall meet specification compliance testing before they may be shipped. Monthly verification samples are not required for these emulsions.

Each manufacturer and supplier shall keep a record of all specification compliance and quality control test results on file for immediate review by the TDOT. All records shall be retained for a minimum of 5 years.

If test results indicate a lot is not in compliance with TDOT Specifications, in addition to the resemblance of Section 9.2 of AASHTO R 26, the supplier must provide a list of all shipments (date, quantity, contract number) to which the questionable material was shipped.

**Quality Assurance (Split samples, random sampling and Round Robin testing)** - The manufacturer shall split samples for specification compliance testing and for quality control testing. Half of each sample shall be retained at the supplier’s facility for a minimum of 30 days to act as a referee sample. The producer shall obtain samples for TDOT verification testing when requested and in the presence of a TDOT inspector (every 30 days).

The TDOT, at any time, may request additional quality control samples to be taken and tested by the supplier or by TDOT, for assurance purposes.

The TDOT, at any time, may request the manufacture or supplier to participate in round robin proficiency testing. TDOT will provide a reasonable time period for the test results to be submitted.
The TDOT will have the right to visit each approved supplier to review quality control activities and records, to obtain random check samples, or to inspect production.

**Contract Sampling**

TDOT will sample and conduct weekly verification testing of contract samples.

Verification testing for emulsions that are more than a week old (as measured from the date of departure from the terminal) will be tested at the contractor’s laboratory by the TDOT plant technician, except if the material is stored in a storage tank by the contractor. Verification testing at the contractor’s plant will only consist of the AASHTO T-59 Sieve Test and the AASHTO T-59 Residue by Evaporation. The test procedures listed in the appendix may be used for quality control only.

Emulsions that are less than a week old or that have been stored by the contractor in a storage tank will be sent to the Headquarters Laboratory for testing. Samples at the headquarters laboratory may be tested for any of the specified requirement listed in the Specification 904.03 or the product specification for QPL items at the Department’s discretion.

If a contract sample is found to be out of compliance, the certification for the load will be deemed no longer valid and the rejected from further use.

**Shipment**- All shipments from the supplier must be accompanied with a completed Form DT-0293Emulsion.

One tanker load may be split between multiple small projects; the projects and estimates shall be declared on the DT-0293Emulsion -Multiple Project form. Quantities used on each project shall be verified by weight tickets prior to and after use on each project.
Appendix A: Rapid Testing Protocol for Quality Control Testing

Method for Rapid Sieve Test

**Purpose:** A rapid method for sieve test of emulsified asphalt for quality control purposes.

**Scope:** This method identifies asphalt particles or other discreet solids larger than #20 mesh.

**Safety:** Utilize safety precautions and personal protective equipment according to facility procedures. Dispose of materials according to facility procedures.

**Equipment:**
- Sieve with #20 mesh on a 76.2-mm frame.
  - Alternatively, a piece of #20 mesh wire cloth approximately 3” by 3”.
- Sieve pan or container to retain residue during drying period.
- Balance capable of weighing 1,000 +/- 1.0 gram.
- Balance capable of weighing 500 +/- 0.1 grams.

**Procedure:**
1. Obtain sample using proper sampling procedure.

2. The temperature of the emulsion sample is related to the emulsion viscosity.
   - A. For emulsions less than 100 SSF @ 25°C perform test at room temperature. Condition sample to room temperature in a closed container using an oven, water bath, or allow the sample to cool on the counter followed by stirring to achieve homogeneity.
   - B. For all other emulsions perform test at 50 ± 3°C. Condition sample to room temperature in a closed container using an oven, water bath, or allow the sample to cool on the counter followed by stirring to achieve homogeneity.

3. Once the sample is conditioned skim the top of the sample to remove any film that may have formed during the conditioning period.

4. Weigh sieve or screen assembly to nearest 0.1 grams.

5. Pour 1,000g +/- 1.0 gram of emulsion through sieve or screen.

6. Gently rinse sieve or screen with distilled water.

7. If no material is retained on the sieve or screen the test is considered passing.

8. If material is retained, remove free water from the bottom and sides of sieve. Care should be used to not disturb particles. Weigh wet assembly. Determine the difference between the wet and dry assembly weights (wet weight). If the difference is less than 1.0 gram (failure threshold) the test is considered passing.

9. If the wet weight exceeds 1.0 gram the sieve assembly will be placed in an oven to dry. During the drying period the assembly can be periodically weighed. At anytime, if the weight gain is less than 1.0 gram (failure threshold) the test will be considered passing.
Method for Rapid Residue by Evaporation Test

**Purpose:** A rapid residue content test method for emulsified asphalt quality control purposes.

**Scope:** This method determines residue content of an asphalt emulsion.

**Safety:** Utilize safety precautions and personal protective equipment according to facility procedures.
Dispose of materials according to facility procedures.

**Equipment:**
- Metal container suitable for evaporation with a capacity large enough to retain material splatter.
- Balance capable of 1,000 +/- 0.1 grams.

**Procedure:**
1. Obtain sample using proper sampling procedure.
2. Tare a metal container and weigh into it 50 +/- 0.1 grams of emulsion.
3. Heat container using a direct flame or hot plate. Splattering can be controlled by adjusting the heat source to prevent localized overheating and by constantly moving container.
4. Continue heating until sample is smooth or has reached a constant weight. Record weight of container and residue.
5. Determine residue. Divide remaining net residue by the original sample weight and multiply by 100.
   A. For CAE-P, AE-P or AE-3 emulsions reported as distillate percentage.
      - Distillate (%) = 100 – Residue (%)
   B. For TST-1P
      - Residue (%) Range, 56 % - 59 %
6. If results fail to meet material specifications the standard distillation or evaporation will be performed.
Method for Rapid Saybolt-Furol Viscosity Test

**Purpose:** A rapid viscosity test method for emulsified asphalt quality control purposes.

**Scope:** This method determines Saybolt-Furol viscosity of an asphalt emulsion.

**Safety:** Utilize safety precautions and personal protective equipment according to facility procedures. Dispose of materials according to facility procedures.

**Equipment:**
- Saybolt-Furol Viscometer.
- Sieve with #20 mesh on a 76.2-mm frame.
  - Alternatively, a piece of #20 mesh wire cloth approximately 3” by 3”.
- Containers suitable for material transfer.
- Timing device capable of counting seconds.

**Procedure:**
1. Obtain sample using proper sampling procedure
2. Inspect viscometer, making sure it is clean, at the proper test temperature, and outlet stopper is in place. Place an approved receiving flask under viscometer outlet.
3. The temperature of the emulsion sample is related to the emulsion viscosity.
   A. For emulsions tested at 77°F - condition approximately 300 grams of emulsion to 78°F – 80°F in a closed container using an oven, water bath or allow to cool on counter followed by stirring to achieve homogeneity.
   B. For emulsions tested at 122°F - condition approximately 300 grams of emulsion to 125°F in a closed container using an oven, water bath or allow to cool on counter followed by stirring to achieve homogeneity.
4. Once the sample is conditioned transfer emulsion through a #20 mesh sieve into the viscometer until a portion begins to overflow into the outer rim.
5. Without further conditioning time, simultaneously remove stopper and start the timer. Emulsion should flow into the receiving flask. Stop timing when flask is filled to fill line.
6. Determine viscosity by multiplying fill time by tube correction factor.
7. If the following limits are exceeded the standard method will be performed:
   - 77°F Viscosity 10 % of Lower Spec. Limit < Vis. < 10 % of Upper Spec. Limit
   - 122°F Viscosity 5 % of Lower Spec. Limit < Vis. < 5 % of Upper Spec. Limit