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Eleven test procedures were previously omitted from the January printing. Add T 2, T 40, T 123, T 217, T 248, T 272, T 716, SOP 730, C 805, T 939, and D 1186 procedures to the current Construction Manual.

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Instructions:
Page numbers and corresponding sheet-counts are given in the table below to indicate portions of the Construction Manual that are to be inserted to accomplish this revision.

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Pages</th>
<th>Sheets</th>
</tr>
</thead>
<tbody>
<tr>
<td>T 2</td>
<td>1-10</td>
<td>5</td>
</tr>
<tr>
<td>T 40</td>
<td>1-4</td>
<td>2</td>
</tr>
<tr>
<td>T 123</td>
<td>1-4</td>
<td>2</td>
</tr>
<tr>
<td>T 217</td>
<td>1-6</td>
<td>3</td>
</tr>
<tr>
<td>T 248</td>
<td>1-8</td>
<td>4</td>
</tr>
<tr>
<td>T 272</td>
<td>1-10</td>
<td>5</td>
</tr>
<tr>
<td>T 716</td>
<td>1-10</td>
<td>5</td>
</tr>
<tr>
<td>SOP 730</td>
<td>1-2</td>
<td>1</td>
</tr>
<tr>
<td>C 805</td>
<td>1-6</td>
<td>3</td>
</tr>
<tr>
<td>T 939</td>
<td>1-6</td>
<td>3</td>
</tr>
<tr>
<td>D 1186</td>
<td>1-8</td>
<td>4</td>
</tr>
</tbody>
</table>

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WSDOT FOP for AASHTO T 2¹
Standard Practice for Sampling Aggregates

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. Attention is directed to Practices E 105 and D 3665.

1.2 The values stated in English inch-pounds units are to be regarded as 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 AASHTO Standards:
   T 248 Reducing Samples of Aggregate to Testing Size

2.2 ASTM Standards:
   C 702 Practice for Reducing Field Samples of Aggregate to Testing Size
   D 2234 Test Method for Collection of a Gross Sample of Coal
   D 3665 Practice for Random Sampling of Construction Materials
   E 105 Practice for Probability Sampling of Materials
   E 122 Practice for Choice of Sample Size to Estimate the Average Quality of a Lot or Process
   E 141 Practice for Acceptance of Evidence Based on the Results of Probability Sampling

3. Significance and Use

3.1 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.

3.2 *When sampling of aggregate sources for preliminary testing, the sampling must be witnessed or taken by a designated representative of the Regional Materials Engineer. The Acceptance samples will be taken by a qualified tester employed by the contracting agency or their designated qualified representative.*

   Samples for preliminary investigation tests are obtained by the agency guidelines (Note 2).
   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.

This Procedure is based on AASHTO T 2-91 (2000).
**Note 2:** 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.

4. **SECURING SAMPLES**

4.1 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.

Native soils within the contract limits to be used for embankment construction and/or backfill material do not require the sampling by a qualified tester. For material that requires gradation testing such as but not limited to manufactured aggregates and Gravel Borrow, a qualified tester shall be required for sampling.

4.2 Inspection — The material shall be inspected to determine discernible variations. The seller shall provide suitable equipment needed for proper inspection and sampling.

4.3 Procedure

4.3.1 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 4.4.2. Take the sample each increment from the entire cross section of the material as it is being discharged. The Standard Specifications require an mechanical, automatic or semi-automatic sampling device be used for processed materials. It is usually necessary to have a special device constructed for use at each 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 3:** 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.

4.3.2 Sampling from the Conveyor Belt (Stopped) — Select units to be sampled by a random method, such as Practice D3665, from the production. Obtain a field sample 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 4.4.2. 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. 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.
4.3.3 Sampling from Stockpiles or Transportation Units — Avoid sampling coarse aggregate or mixed coarse and fine aggregate from stockpiles or 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 stockpile of coarse aggregate or a stockpile of combined coarse and fine aggregate, design a sampling plan for the specific case under consideration. This approach will allow the sampling agency to use a sampling plan that will give a confidence in results obtained there from 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. For general guidance in sampling from stockpiles, see the Appendix.

4.3.4 Sampling from Roadway (Bases and Subbases) — WSDOT has deleted this section.

4.4 Number and Masses of Field Samples

4.4.1 The number of field samples (obtained by one of the methods described in 4.3) 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 4: Guidance for determining the number of samples required to obtain the desired level of confidence in test results may be found in Test Method D 2234, Practice E 105, Practice E 122, and Practice E 141.

4.4.2 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 T 248 or as required by other applicable test methods.

5. SHIPPING SAMPLES

5.1 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. The weight limit for each bag of aggregate is 30 pounds maximum.

5.2 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. All samples submitted for testing to the Region or State Materials Laboratories shall be accompanied by completed sample transmittal (WSDOT Form 350-056) or equivalent.
## Table 1
Size of Samples

<table>
<thead>
<tr>
<th>Maximum Nominal Size of Aggregates&lt;sup&gt;A&lt;/sup&gt;</th>
<th>Approximate Minimum Mass of Field Samples, kg&lt;sup&gt;B&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fine Aggregate</strong></td>
<td></td>
</tr>
<tr>
<td>2.36 mm</td>
<td>10</td>
</tr>
<tr>
<td>4.75 mm</td>
<td>10</td>
</tr>
<tr>
<td><strong>Coarse Aggregate</strong></td>
<td></td>
</tr>
<tr>
<td>9.5 mm</td>
<td>10</td>
</tr>
<tr>
<td>12.5 mm</td>
<td>15</td>
</tr>
<tr>
<td>19.0 mm</td>
<td>25</td>
</tr>
<tr>
<td>25.0 mm</td>
<td>50</td>
</tr>
<tr>
<td>37.5 mm</td>
<td>75</td>
</tr>
<tr>
<td>50 mm</td>
<td>100</td>
</tr>
<tr>
<td>63 mm</td>
<td>125</td>
</tr>
<tr>
<td>75 mm</td>
<td>150</td>
</tr>
<tr>
<td>90 mm</td>
<td>175</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nominal Maximum Size&lt;sup&gt;A&lt;/sup&gt; in (mm)</th>
<th>Minimum Mass&lt;sup&gt;B&lt;/sup&gt; in lb (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US No. 4 (4.75)</td>
<td>5 (2)</td>
</tr>
<tr>
<td>1/4 (6.3)</td>
<td>10 (4)</td>
</tr>
<tr>
<td>3/8 (9.5)</td>
<td>10 (4)</td>
</tr>
<tr>
<td>1/2 (12.5)</td>
<td>20 (8)</td>
</tr>
<tr>
<td>5/8 (16.0)</td>
<td>20 (8)</td>
</tr>
<tr>
<td>3/4 (19.0)</td>
<td>30 (12)</td>
</tr>
<tr>
<td>1 (25.0)</td>
<td>55 (25)</td>
</tr>
<tr>
<td>11/4 (31.5)</td>
<td>70 (30)</td>
</tr>
<tr>
<td>11/2 (37.5)</td>
<td>80 (36)</td>
</tr>
<tr>
<td>2 (50)</td>
<td>90 (40)</td>
</tr>
<tr>
<td>21/2 (63)</td>
<td>110 (50)</td>
</tr>
<tr>
<td>3 (75)</td>
<td>140 (60)</td>
</tr>
<tr>
<td>31/2 (90)</td>
<td>180 (80)</td>
</tr>
</tbody>
</table>

<sup>A</sup>For aggregate, the nominal maximum size, (NMS) is the largest standard sieve opening listed in the applicable specification, upon which any material is permitted to be retained. For concrete aggregate, NMS is the smallest standard sieve opening through which the entire amount of aggregate is permitted to pass.

<sup>A</sup>For processed aggregate the nominal maximum size of particles is the largest sieve size listed in the applicable specification, upon which any material is permitted to be retained.

<sup>B</sup>For combined coarse and fine aggregates (for example, base or subbase) minimum weight shall be coarse aggregate minimum plus 10 kg.

**Note 5:** For an aggregate specification having a generally unrestricted gradation (i.e., wide range of permissible upper sizes), where the source consistently fully passes a screen substantially smaller than the maximum specified size, the nominal maximum size, for the purpose of defining sampling and test specimen size requirements may be adjusted to the screen, found by experience to retain no more than 5% of the materials.
APPENDIXES

XI. SAMPLING AGGREGATE FROM STOCKPILES OR TRANSPORTATION UNITS

X1.1 Scope

X1.1.1 In some situations it is mandatory to sample aggregates that have been stored in stockpiles or loaded into rail cars, barges, or trucks. In such cases the procedure should ensure that segregation does not introduce a serious bias in the results.

X1.2 Sampling From Stockpiles

X1.2.1 In sampling material from stockpiles it is very difficult to ensure unbiased samples, due to the segregation which often occurs when material is stockpiles, with coarser particles rolling to the outside base of the pile. For coarse or mixed coarse and fine aggregate, every effort should be made to enlist the services of power equipment, such as a front end loader, to develop a separate, small sampling pile composed of materials drawn from various levels and locations in the main pile after which several increments may be combined to compose the field sample. If necessary to indicate the degree of variability existing within the main pile, separate samples should be drawn from separate areas of the pile.

X1.2.2 Where power equipment is not available, samples from stockpiles should be made up of at least three increments taken from the top third, at the mid-point, and at the bottom third of the volume of the pile. A board shoved vertically into the pile just above the sampling point aids in preventing further segregation. In sampling stockpiles of fine aggregate the outer layer, which may have become segregated, should be removed and the sample taken from the material beneath. Sampling tubes approximately 1½ in. (30-mm) min by 6 ft. (2-m) min in length may be inserted into the pile at random locations to extract a minimum of five increments of material to form the sample.

X1.3 Sampling From Transportation Units

X1.3.1 In sampling coarse aggregates from railroad cars or barges, effort should be made to enlist the services of power equipment capable of exposing the material at various levels and random locations. Where power equipment is not available, a common procedure requires excavation of three or more trenches across the unit at points that will, from visual appearance, give a reasonable estimate of the characteristics of the load. The trench bottom should be approximately level, at least 1 ft. (0.3 m) in width and in depth below the surface. A minimum of three increments from approximately equally spaced points along each trench should be taken by pushing a shovel downward into the material. Coarse aggregate in trucks should be sampled in essentially the same manner as for rail car or barges, except for adjusting the number of increments according to the size of the truck. For fine aggregate in transportation units, sampling tubes as described in X1.2 may be used to extract an appropriate number of increments to form the sample.
X2. EXPLORATION OF POTENTIAL AGGREGATE SOURCES

X2.1 Scope

X2.1.1 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.

X2.2 Sampling Stone from Quarries of Ledges

X2.2.1 Inspection — The ledge or quarry face should be inspected to determine discernible variations or strata. Differences in color and structure should be recorded.

X2.2.2 Sampling and Size of Sample — Separate samples having a mass of at least 55 lbs (25 kg) 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 6 X 6 X 4 inch (150 by 150 by 100 mm) in size with the bedding plane plainly marked, and this piece should be free of seams or fractures.

X2.2.3 Record — In addition to the general information accompanying all samples the following information should accompany samples taken from ledges or quarry faces:

X2.2.3.1 Approximate quantity available. (If quantities is very large this may be recorded as practically unlimited.)

X2.2.3.2 Quantity and character of overburden.

X2.2.3.3 A detailed record showing boundaries and location of material represented by each sample.

Note X2.1: A sketch, plan, and elevation, showing the thickness and location of the different layers is recommended for this purpose.

X2.3 Sampling Roadside or Bank Run Sand and Gravel Deposits

X2.3.1 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.

X2.3.2 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 25 lb (12 kg) for sand and 75 lb (35 kg) if the deposit contains an appreciable amount of coarse aggregate.
X2.3.3 Record — In addition to the general information accompanying all samples the following information should accompany samples of bank run sand and gravel:

X2.3.3.1 Location of supply.
X2.3.3.2 Estimate of approximate quantity available.
X2.3.3.3 Quantity and character of overburden.
X2.3.3.4 Length of haul to proposed site of work.
X2.3.3.5 Character of haul (kind of road, maximum grades, etc.)
X2.3.3.6 Details as to extent and location of material represented by each sample.
Performance Exam Checklist

Sampling of Aggregates
FOP for AASHTO T 2

Participant Name _______________________________ Exam Date ________________

Procedure Element

1. The tester has a copy of the current procedure on hand?

Conveyor Belts –Stopped

2. Belt stopped?

3. Sampling device set on belt, avoiding intrusion of adjacent material?

4. Sample, including all fines, scooped off?

Flowing Aggregate Sampler

5. Container passed through full stream of material as it runs off end of belt? (Mechanical, Automatic or Semi Automatic Sampler Only)

Transport Units

6. Three or more trenches cut across the unit?

7. Trench bottom level and approximate 1 foot wide and 1 foot below surface of material in unit?

8. Three samples taken at equal spacing along each trench?

Stockpiles

9. Create vertical face, if one does not exist, or use mechanical equipment to build a small sampling pile?

10. At least three increments taken, at various locations?

Procedure Element

11. If vertical face cannot be created, increment taken from at least three locations from top, middle, and bottom?

12. When sampling sand, outer layer removed and increments taken from a least five locations?

First attempt: Pass ☐ Fail ☐ Second attempt: Pass ☐ Fail ☐

Signature of Examiner __________________________________________
SIGNIFICANCE

The quality of bituminous materials has a tremendous impact on a roadway project. The grade of binder selected is based on a number of factors, including local temperature extremes and characteristics of expected traffic. Using a grade of binder material other than that specified will have serious impacts on roadway performance and durability.

SCOPE

The procedure covers obtaining samples of liquid bituminous materials in accordance with AASHTO T 40. Sampling of solid and semi-solid bituminous materials (included in AASHTO T 40) is not covered here.

Agencies may be more specific on exactly who samples, where to sample, and what type of sampling device to use.

WSDOT personnel need to observe the contractor’s personnel sampling to assure that proper sampling procedures are followed.

If proper sampling procedures are not followed it shall be noted on the sample transmittal “Proper sampling procedures not followed.” See WSDOT Standard Specification 1-06.

PROCEDURE

1. Coordinate sampling with contractor or supplier.
2. Use appropriate safety equipment and precautions.
3. Allow a minimum of 1 gal (4 L) to flow before obtaining samples.
4. Obtain samples of:
   - Asphalt binder from Hot Mix Asphalt (HMA) Plant from the line between the storage tank and the mixing plant or the storage tank while the plant is in operation, or from the delivery truck.
   - Cutback and Emulsified asphalt from distributor spray bar or application device; or from the delivery truck before it is pumped into the distributor. Sample emulsified asphalt at delivery or prior to dilution.

CONTAINERS

Sample containers must be new, and the inside may not be washed or rinsed. The outside may be wiped with a clean, dry cloth.

All samples shall be put in 1 qt (1 L) containers and properly identified on the outside of the container with contract number, date sampled, data sheet number, brand and grade of material, and sample number. Include lot and subplot numbers when appropriate.

Note: The filled sample container shall not be submerged in solvent, nor shall it be wiped with a solvent saturated cloth. If cleaning is necessary, use a clean dry cloth.

- Emulsified asphalt: Use wide-mouth plastic jars with screw caps. Protect the samples from freezing since water is a part of the emulsion.
- Asphalt binder & Cutbacks: Use metal cans.

Standard sample labels (WSDOT Form 350-016) shall be completely filled out and attached to each sample container.
Performance Exam Checklist

**Sampling Bituminous Materials**

WAQTC FOP for AASHTO T 40

<table>
<thead>
<tr>
<th>Procedure Element</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The tester has a copy of the current procedure on hand?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Appropriate containers used?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Wide-mouth plastic containers (emulsified).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Metal cans (all other bituminous liquids).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Containers not washed or rinsed on inside?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Minimum of 1 gallon allowed to flow before sample taken?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Material obtained at correct location?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Line between storage tank and mixing plant or the storage tank (HMA plants).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Spray bar or application device, if not diluted (distributors).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. From delivery vehicle or prior to dilution, if diluted (distributors).</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sample taken by: Contractor □  WSDOT □

First attempt:  Pass □  Fail □  Second attempt:  Pass □  Fail □

Signature of Examiner __________________________________________

Comments:

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
WSDOT Test Method T 123

Method of Test for Bark Mulch

1. SCOPE
   a. This method covers a procedure for determining the sieve analysis and material finer than 1/4 in. using a loose volume bucket.

2. EQUIPMENT
   a. A mechanical sieve shaker.
   b. Sieves — A 1 1/2 in. and No. 4 sieves conforming to the requirements of AASHTO M-92. Breaker sieves may be used.
   c. Volume Bucket — A container calibrated in 1 gal. increments from 1 to 5 gal. A 5-gal. bucket may be used when calibrated as follows:
      On a level surface calibrate the container by gradually filling it with water in 1 gal. increments. Mark the inner wall of the container after the addition of each gallon

3. PROCEDURE
   a. Air dry (140°F max.) the sample for 15 hours, ± 4 hours.
   b. Reduce the sample to testing size per the FOP for AASHTO T 248.
   c. Place the sample in the volume bucket and record the volume as the total volume.
   d. Shake the sample over the 1 1/2 in. and No. 4 sieves. Using breaker sieves inserted between the two specified sieves so the No. 4 sieve will not be overloaded. Use caution to avoid over sieving as the wood material breaks down.
   e. The material retained on the 1 1/2 in. sieve is measured in the volume bucket and recorded.
   f. The material on the breaker sieves is added to the material retained on the No. 4 sieve and the volume measured in the volume bucket and recorded.
   g. The percent passing is calculated as follows:

\[ 100 - \frac{(Volume \ on \ sieve \times 100)}{Total \ Volume} = \% \ passing \]
**Method of Test for Bark Mulch**  
**WSDOT T 123**

**Performance Exam Checklist**

<table>
<thead>
<tr>
<th>Procedure Element</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The tester has a copy of the current procedure on hand?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. All equipment is functioning according to the test procedure,</td>
<td></td>
<td></td>
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<tr>
<td>and if required, has the current calibration/verification tags present?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Bark mulch sample dried for 15 ± 4 hrs @ 140°F?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Five (5) gallon bucket calibrated in 1 gal. increments?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Sample quartered or split and placed in calibrated bucket?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Volume of sample in bucket recorded as total volume?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Sample screened in the shaker through 1½ in.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>screen, breaker screens and No. 4 screen?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Do not over shake to prevent degrading of sample?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Remove 1½ in. screen and damp material in calibrated bucket and record volume as volume on 1½ in. screen?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Place all breaker screen material down to No. 4 screen in bucket and record volume as volume on No. 4 screen?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. All calculations performed correctly?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Report results?</td>
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<tr>
<td>First attempt: Pass ☐ Fail ☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second attempt: Pass ☐ Fail ☐</td>
<td></td>
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</table>

Signature of Examiner __________________________________________________________

Comments:

__________________________________________________________________________

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WSDOT FOP for AASHTO T 217

Determination of Moisture in Soils by Means of a Calcium Carbide Gas Pressure Moisture Tester

1. SCOPE

1.1 This method of test is intended to determine the moisture content of soils by means of a calcium carbide gas pressure moisture tester. The manufacturer’s instructions shall be followed for the proper use of the equipment.

1.2 The following applies to all specified limits in this standard: For the purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded off “to the nearest unit” in the last right-hand place of figures used in expressing the limiting value, in accordance with R 11, Recommended Practice for Indicating Which Places of Figures Are to Be Considered Significant in Specified Limiting Values.

Note 1: This method shall not be used on granular materials having particles large enough to affect the accuracy of the test in general any appreciable amount retained on a No. 4 (4.75-mm) sieve. The super 200 D tester is intended to be used to test aggregate.

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

1.4 Refer to R 16 for regulatory information for chemicals.

2. REFERENCED DOCUMENT

2.1 AASHTO Standards:

R 11, Indicating Which Places of Figures Are to Be Considered Significant in Specified Limiting Values

T 265, Laboratory Determination of Moisture Content of Soils

3. APPARATUS

3.1 Calcium carbide pressure moisture test – a chamber with attached pressure gage for the water content of specimens having a mass of at least 20 g. (Figure 1).

Those “Speed Moisture Testers” which use a 20 g sample may be used to test aggregates and soil-aggregate mixtures where the maximum particle size is 3/4 in. (20 mm) or less.

3.2 Balance – shall conform to AASHTO M 231, Class G-2.

3.3 Two 1.25-in. (31.75-mm) steel balls

3.4 Cleaning brush and cloth.

3.5 Scoop for measuring calcium carbide reagent.

This FOP is based on AASHTO T 217-02
4. MATERIAL

4.1 Calcium carbide reagent.

*Note 2:* The calcium carbide must be finely pulverized and should be of a grade capable of producing acetylene gas in the amount of at least 2.25 ft³/lb (0.14 m³/kg) of carbide.

*Note 3:* The “shelf life” of the calcium carbide reagent is limited, so it should be used according to the manufacturer’s recommendations. When a can of calcium carbide is opened, it shall be dated. After 3 months of use, or if the can becomes contaminated, it shall be discarded.

5. PROCEDURE

5.1 When using the 20-g or 26-g tester, place three scoops (approximately 24g) of calcium carbide in the body of the moisture tester (or per the manufacturers recommendations). When using the super 200 D tester to test aggregate, place six scoops (approximately 48 g) of calcium carbide in the body of the moisture tester.

*Note 4:* Care must be exercised to prevent the calcium carbide from coming into direct contact with water.

5.2 Weigh a sample of the exact mass specified by the manufacturer of the instrument in the balance provided, and place the sample in the cap of the tester. When using the 20-g or 26-g size tester, place two 1.25-in. (31.75-mm) steel balls in the body of the tester with the calcium carbide (or per the manufacturers recommendations).

*Note 5:* Manufacturer’s instructions shall be followed for the use of steel balls, particularly when testing sand.

*Note 6:* If the moisture content of the sample exceeds the limit of the pressure gage (12 percent moisture for aggregate tester to 20-percent moisture for soil tester), a one-half size sample must be used and the dial reading must be multiplied by 2. This proportional method is not directly applicable to the dry mass percent scale on the super 200 D tester.

5.3 With the pressure vessel in an approximately horizontal position, insert the cap in the pressure vessel and seal the unit by tightening the clamp, taking care that no carbide comes in contact with the soil until a complete seal is achieved.
5.4 Raise the moisture tester to a vertical position so that the soil in the cap will fall into the pressure vessel.

5.5 Shake the instrument vigorously so that all lumps will be broken up to permit the calcium carbide to react with all available free moisture. When steel balls are being used in the tester and when using the large tester to test aggregate, the instrument should be shaken with a rotating motion so the steel balls or aggregate will not damage the instrument or cause soil particles to become embedded in the orifice leading to the pressure diaphragm.

Note 7: Shaking should continue for at least 60 seconds with granular soils and for up to 180 seconds for other soils so as to permit complete reaction between the calcium carbide and the free moisture. Time should be permitted to allow dissipation of the heat generated by the chemical reaction.

5.6 When the needle stops moving, read the dial while holding the instrument in a horizontal position at eye level.

5.7 Record the sample mass and the dial reading.

5.8 With the cap of the instrument pointed away from the operator, and away from open flame or source of ignition, slowly release the gas pressure. Empty the pressure vessel and examine the material for lumps. If the sample is not completely pulverized, the test should be repeated using a new sample. Clean the cap thoroughly of all carbide and soil before running another test.

Note 8: When removing the cap, care should be taken to point the instrument away from the operator to avoid breathing the fumes, and away from any potential source of ignition for the acetylene gas.

5.9 The dial reading is the percent of moisture by wet mass and must be converted to dry mass. With the super 200 D tester the dial reading is the percent of moisture by dry mass, and no further calculation is required.

6. CALCULATION

6.1 The percentage of moisture by dry mass of the soil may be determined from a correction curve similar to Figure 2.

6.2 A correction curve similar to Figure 2 is normally supplied with each moisture tester. Each moisture tester, however, should be checked for the accuracy of its gage, and for the accuracy of its correction curve.

5.2.1 The accuracy of the moisture tester gage should be checked by using a calibration kit (available from the manufacturer), equipped with a standard gage. In case of discrepancy, the gage on the tester should be adjusted to conform with the standard gage.

5.2.2 The accuracy of the correction curve should be checked by comparing curve-corrected moisture contents to moisture contents of locally prepared soils determined using T 265. In case of discrepancy, develop a new correction curve based on moisture contents determined from T 265.
5.2.3 The range of the factory-supplied or laboratory-determined curves may be extended by additional testing.

Figure 2 —Correction Curve for Moisture Tester Reading (Example Only—Use curve provided by the manufacturer with the specific apparatus, or a correction curve calibrated or extended for local soils at known moisture contents determined in accordance with 6.2.)

Note 9: It may be more convenient for field use of the apparatus to prepare a table of moisture tester readings versus oven-dry moisture content for the moisture tester.

6.3 Determine the percentage of moisture to the nearest whole percent.
## Performance Exam Checklist

**Determination of Moisture in Soils by Means of Calcium Carbide Gas Pressure Moisture Tester**  
**FOP for AASHTO T 217**

<table>
<thead>
<tr>
<th>Participant Name</th>
<th>________________</th>
<th>Exam Date</th>
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### Procedure Element

<table>
<thead>
<tr>
<th>Procedure Element</th>
<th>Yes</th>
<th>No</th>
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<tbody>
<tr>
<td>1. The tester has a copy of the current procedure on hand?</td>
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<tr>
<td>2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?</td>
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<tr>
<td>3. Shelf life of calcium carbide reagent checked?</td>
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<tr>
<td>4. Correct amount of reagent placed in body of tester?</td>
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<td>5. Number and size of steel balls correct?</td>
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<td>6. Correct mass of moist soil placed in cap of tester?</td>
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<td>7. Cap clamped to body with tester in horizontal position?</td>
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<tr>
<td>8. Shaking done for proper time (60 seconds for granular soils, 180 seconds for other soils)?</td>
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<tr>
<td>9. Shaking done without steel balls hitting cap or bottom of tester?</td>
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<td>10. Reading taken with tester in horizontal position at eye level?</td>
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<td>11. Reading taken after gauge stops moving?</td>
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<td>12. Gauge reading recorded?</td>
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<tr>
<td>13. Tester positioned with cap away from user and away from open flame or source of ignition before gas slowly released?</td>
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<tr>
<td>14. Moisture content on wet mass basis converted to dry mass basis?</td>
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</table>

First attempt:  Pass ☐  Fail ☐  Second attempt:  Pass ☐  Fail ☐

Signature of Examiner __________________________________________

Comments:

________________________________________________________________________________________________________

________________________________________________________________________________________________________
WSDOT FOP for AASHTO T 248

Reducing Samples of Aggregate to Testing Size

1. Scope
   1.1 This method covers for the reduction of large samples of aggregate to the appropriate size for testing employing techniques that are intended to minimize variations in measured characteristics between the test samples so selected and the large sample.
   1.2 The values stated in English units are to be regarded as 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 AASHTO Standards:
       T 2 Sampling of Aggregate
       T 84 Specific Gravity and Absorption of Coarse Aggregate
   2.2 ASTM Standards:
       C 125 Terminology Relating to Concrete and Concrete Aggregates

3. Terminology
   3.1 Definitions — The terms used in this practice are defined in ASTM C 125.

4. Significance and Use
   4.1 Specifications for aggregates require sampling portions of the material for testing. Other factors being equal, larger samples will tend to be more representative of the total supply. These methods provide for reducing the large sample obtained in the field or produced in the laboratory to a convenient size for conducting a number of tests to describe the material and measure its quality in a manner that the smaller test sample portion is most likely to be a representation of the larger sample, and thus of the total supply. 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, as 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 as a few discrete fragments 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.

1This FOP is based on AASHTO T 248-02.
4.3 Failure to carefully follow the procedures in this practice could result in providing a nonrepresentative sample to be used in subsequent testing.

5. SELECTION OF METHOD

5.1 Fine Aggregate — Samples of fine aggregate that are drier than the drier saturated-surface-dry condition or drier (Note 1) may be reduced using a mechanical splitter according to Method A. Samples having free moisture on the particle surfaces may be reduced in size 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, the sample may be moistened to achieve this condition, thoroughly mixed, and then the sample reduction performed.

Note 1: The method of determining the saturated-surface-dry condition is described in Test Method T 84. 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.

5.1.2 If use of Method A is desired and the sample has free moisture on the particle surfaces, the entire sample may be dried to at least the saturated-surface-dry condition, using temperatures that do not exceed those specified for any of the tests contemplated, and then the sample reduction performed. Alternatively, if the moist sample is very large, a preliminary split may be made using a mechanical splitter having wide chute openings of 1 1/2 in. (38 mm) or more to reduce the sample to not less than 5000 g. The portion so obtained is then dried, and reduction to test sample size is completed using Method A.

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.

5.3 Untreated materials shall be prepared for testing using this procedure. Treated materials (i.e., Hot Mix Asphalt or Asphalt Treated Base) shall be prepared for testing using WSDOT Test Method No. T 712 for reduction of size of samples of Asphalt treated materials.

6. SAMPLING

6.1 The samples of aggregate obtained in the field shall be taken in accordance with T 2, or as required by individual test methods. When tests for sieve analysis only are contemplated, the size of field sample listed in T 2 is usually adequate. When additional tests are to be conducted, the user shall determine that the initial size of the field sample is adequate to accomplish all intended tests. Similar procedures shall be used for aggregate production 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 12 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 percent larger than the largest particles in the sample to be split (Note 2). For dry fine aggregate in which the entire sample will pass the 3/8 in. (9.5 mm) sieve, the minimum width of the individual chutes shall be at least 50 percent larger than the largest particles in the sample and the maximum width shall be 3/4 in. (19 mm). The splitter shall be equipped with two receptacles to hold the two-halves of the sample following splitting. It shall also be equipped with a hopper or straight edge pan which has a width equal to or slightly less than the overall width of the assembly of chutes, 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 (Figure 1).

![Diagram of Sample Dividers (Riffles)](image)

**Figure 1: Sample Dividers (Riffles)**
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. The rate at which the sample is introduced shall be such as to allow free flowing through the chutes into the receptacles below. Reintroduce the portion of the sample in one of the receptacles into the splitter as many times as necessary to reduce the sample to the size specified for the intended test. The portion of the material collected in the other receptacle may be reserved for reduction in size for other tests.

Method B — Quartering

9. APPARATUS

9.1 Apparatus shall consist of a straightedge, scoop, shovel, or trowel; a broom or brush; and a canvas blanket approximately 6 by 8 ft. (2 by 2.5 m).

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 (Figure 2).

![Figure 2: Quartering on a Hard, Clean Level Surface](image-url)
10.1.2  As an alternative to the procedure in 10.1.1 when the floor surface is uneven, the field sample may be placed on a canvas blanket and mixed with a shovel as described in 10.1.1, or by alternatively 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 (Figure 3).

Figure 3: Quartering on a Canvas Blanket
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, the conical pile may be flattened to a uniform thickness and diameter by pressing 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 from the miniature stockpile, using any of the sampling devices described in 11.1.
Performance Exam Checklist

Reducing Samples of Aggregates to Testing Size
FOP for AASHTO T 248

<table>
<thead>
<tr>
<th>Participant Name</th>
<th>Exam Date</th>
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<tbody>
<tr>
<td>1. The tester has a copy of the current procedure on hand?</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

Selection of Method

1. Fine Aggregate
   A. Saturated surface dry or drier: Method A (Splitter) used? | ☐ | ☐ |
   B. Free moisture present: Method B (Quartering) used? | ☐ | ☐ |

2. Coarse Aggregate and Mixtures of Fine and Coarse Aggregates
   A. Method A used (preferred)? | ☐ | ☐ |
   B. Method B used? | ☐ | ☐ |

Method A — Splitting

1. Material spread uniformly on feeder? | ☐ | ☐ |
2. Rate of feed slow enough so that sample flows freely through chutes? | ☐ | ☐ |
3. Material in one pan re-split until desired mass is obtained? | ☐ | ☐ |
4. Chutes are set correctly for material being split? | ☐ | ☐ |

Method B — Quartering

1. Sample placed on clean, hard, and level surface? | ☐ | ☐ |
2. Mixed by turning over 3 times with shovel or by raising canvas and pulling over pile? | ☐ | ☐ |
3. Conical pile formed? | ☐ | ☐ |
4. Diameter equal to about 4 to 8 times thickness? | ☐ | ☐ |
5. Pile flattened to uniform thickness and diameter? | ☐ | ☐ |
6. Divided into 4 equal portions with shovel or trowel? | ☐ | ☐ |
7. Two diagonally opposite quarters, including all fine material, removed? | ☐ | ☐ |
8. Cleared space between quarters brushed clean? □ □

9. Process continued until desired sample size is obtained when two opposite quarters combined? □ □

_The sample may be placed upon a blanket and a stick or pipe may be placed under the blanket to divide the pile into quarters._

First attempt: Pass □ Fail □
Second attempt: Pass □ Fail □

Signature of Examiner __________________________________________

Comments:

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T 248 January 2007 T 248
WSDOT FOP for AASHTO T 272¹

Family of Curves — One-point Method

1. SCOPE

1.1 These methods of tests are for the rapid determination of the maximum density and optimum moisture content of a soil sample utilizing a family of curves and a one-point determination.

1.2 One-point determinations are made by compacting the soil in a mold of a given size with a 5.5-lb (2.5-kg) rammer dropped from a height of 12 in. (305 mm). Four alternate procedures are provided as follows:

   Method A — A 4-in. (101.6 mm) mold; soil material passing a No. 4 (4.75-mm) sieve. Sections 4 and 5.

   Method B — A 6-in. (152.4-mm) mold; soil material passing a No. 4 (4.75-mm) sieve. Sections 6 and 7.

   Method C — A 4-in. (101.6 mm) mold; soil material passing a ³⁄₄ in. (19.0-mm) sieve. Sections 8 and 9.

   Method D — A 6-in. (152.4-mm) mold; soil material passing a ³⁄₄ in. (19.0-mm) sieve. Sections 10 and 11.

The preferred method of WSDOT is to use method A.

1.3 The methods described herein correspond to the methods in T 99 and must be chosen accordingly; i.e., when moisture-density relationships as determined by T 99 Method C are used to form the family of curves, then Method C described in this procedure must be used for the one-point determination (Note 1).

Note 1: Direct reference to T 99 is made throughout these test methods and most terminology, apparatus and procedures are the same.

1.4 In addition, the concepts described herein are applicable to one-point determinations and moisture-density relationships as specified in T 180 with appropriate apparatus and method used as required.

1.5 The following applies to all specified limits in this standard: For the purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded off “to the nearest unit” in the last right-hand place of figures used in expressing the limiting value, in accordance with the rounding-off method of R 11, Recommended Practice for Indicating Which Places of Figures Are to Be Considered Significant in Specified Limiting Values.

1.6 The values stated in English units are to be regarded as the standard.

¹This FOP is based on AASHTO T 272-04
FIGURE 1  Example of Curves
2. REFERENCED DOCUMENTS

2.1 AASHTO Standards:

- R 11, Indicating Which Places of Figures Are to Be Considered Significant in Specified Limiting Values
- T 19/T 19M, Bulk Density (“Unit Weight”) and Voids in Aggregate
- T 99, Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop
- T 180, Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in.) Drop

3. DEFINITION

3.1 A family of curves is a group of typical soil moisture-density relationships determined using T 99, which reveal certain similarities and trends characteristic of the soil type and source. Soils sampled from one source will have many different moisture-density curves, but if a group of these curves are plotted together certain relationships usually become apparent. In general it will be found that higher unit mass soils assume steeper slopes with maximum dry densities at lower optimum moisture contents, while the lower unit mass soils assume flatter more gently sloped curves with higher optimum moisture contents (Figure 1).

4. APPARATUS

4.1 See T 99, Section 3.

METHOD A

5. SAMPLE

5.1 See T 99, Section 4.

6. PROCEDURE

6.1 Thoroughly mix the selected representative sample with sufficient water to dampen approximately 4 percentage points below optimum moisture content. Greater accuracy in the determination of the maximum density will result as the moisture content used approaches optimum moisture content. Moisture content of the sample should never exceed the optimum water content. When doing a one-point determination in the field, use the sample as obtained and determine the moisture after the test.

6.2 Form a specimen by compacting the prepared soil in the 4-in. (101.6-mm) mold (with collar attached) in three approximately equal layers to give a total compacted depth of about 5 in. (125 mm). Compact each layer by 25 uniformly distributed blows from the rammer dropping free from a height of 12 in. (305 mm) above the elevation of the soil when a sleeve-type rammer is used, or from 12 in. (305 mm) above the approximate elevation of compacted soil when a stationary mounted type of rammer is used. During compaction, the mold shall rest firmly on a dense uniform, rigid and stable foundation (Note 2).

Note 2: Each of the following has been found to be a satisfactory base on which to rest the mold during compaction of the soil: A block of concrete, with a mass not less than 200 lb (91 kg) supported by a relatively stable foundation; a sound concrete floor; and for field application, such surfaces as are found in concrete box culverts, bridges, and pavements.
6.2.1 Following compaction, remove the extension collar, carefully trim the compacted soil even with the top of the mold by means of the straightedge, and determine the mass of the mold and moist soil in kilograms to the nearest 5 grams, or determine the mass in pounds to the nearest 0.01 pounds. For molds conforming to tolerances given in T 99 and masses recorded in kilograms, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 1060, and record the result as the wet density, \( W_1 \), in kilograms per cubic meter, of compacted soil. For molds conforming to tolerances given in T 99 and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 30, and record the result as the wet density, \( W_1 \), in pounds per cubic foot, of compacted soil. For used molds out of tolerance by not more than 50 percent (T 99), use the factor for the mold as determined in accordance with AASHTO T 19.

6.3 Remove the material from the mold and slice vertically through the center. Take a representative sample of the material from one of the cut faces, determine the mass immediately, and dry in an oven at 110 ± 5°C (230 ± 9°F), for at least 12 hours, or to a constant mass to determine the moisture content in accordance with AASHTO T 255 or T 217. The moisture sample shall have a mass not less than 100 g.

**WSDOT Note** — When developing a compaction curve for free draining soils, such as uniform sands and gravels, where seepage occurs at the bottom of the mold and base plate, taking a representative moisture content sample from the mixing bowl may be preferred in order to determine the amount of moisture available for compaction.

**METHOD B**

7. **SAMPLE**

7.1 Select the representative sample in accordance with Section 4, except that it shall have a mass of approximately 16 lb (7 kg).

8. **PROCEDURE**

8.1 Follow the same procedure as described for Method A in Section 5, except for the following: Form a specimen by compacting the prepared soil in the 6-in. (152.4-mm) mold (with collar attached) in three approximately equal layers to give a total compacted depth of about 5-in. (125 mm), each layer being compacted by 56 uniformly distributed blows from the rammer. For molds conforming to tolerances given in T 99, and masses recorded in kilograms, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 471, and record the result as the wet density, \( W_1 \), in kilograms per cubic meter of compacted soil. For molds conforming to tolerances given in T 99, and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 13.33, and record the result as the wet density, \( W_1 \), in pounds per cubic foot, of the compacted soil. For used molds out of tolerance by not more than 50 percent (T 99), use the factor for the mold as determined in accordance with AASHTO T 19.

**METHOD C**

9. **SAMPLE**

9.1 If the soil sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying bay be in air or by use of drying apparatus such that the temperature does not exceed 140°F (60°C). Then thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of individual particles.
9.2 Sieve an adequate quantity of the representative pulverized soil over the \( \frac{3}{4} \) in. (19.0-mm) sieve. Discard the coarse material, if any, retained on the \( \frac{3}{4} \) in. (19.0-mm) sieve (Note 3).

*Note 3:* The use of a replacement method, where the oversized particles are replaced with finer particles to maintain the same percentage of coarse material, is not considered appropriate to compute the maximum density.

9.3 Select a representative sample having a mass of approximately 12 lb (5 kg) or more of the soil prepared as described in Sections 9.1 and 9.2.

10. PROCEDURE

10.1 Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately 4 percentage points below optimum moisture content. Greater accuracy in the determination of the maximum density will result as the moisture content used approaches the optimum moisture content.

10.2 Form a specimen by compacting the prepared soil in the 4-in. (101.6-mm) mold (with collar attached) in three approximately equal layers to give total compacted depth of about 5 in. (125 mm). Compact each layer by 25 uniformly distributed blows from the rammer dropping free from a height of 12 in. (305 mm) above the elevation of the soil when a sleeve-type rammer is used or from 12 in. (305 mm) above the approximate elevation of each finely compacted layer when a stationary mounted type rammer is used. During compaction, the mold shall rest firmly on a dense, uniform, rigid and stable foundation (Note 2).

10.2.1 Following compaction, remove the extension collar and carefully trim the compacted soil even with the top of the mold by means of the straightedge. Holes developed in the surface by removal of coarse material shall be patched with smaller size material. Determine the mass of the mold and moist soil in kilograms to the nearest 5 grams, or determine the mass in pounds to the nearest 0.01 pounds. For molds conforming to tolerances given in T 99 and masses recorded in kilograms, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 1060, and record the result as the wet density, \( W_1 \), in kilograms per cubic meter of compacted soil. For molds conforming to tolerances given in T 99 and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 30, and record the result as the wet density, \( W_1 \), in pounds per cubic foot, of compacted soil. For used molds out of tolerance by not more than 50 percent (T 99), use the factor for the mold as determined in accordance with T-19.

10.3 Remove the material from the mold and slice vertically through the center. Take a representative sample of the material from one of the cut faces, determine the mass immediately and dry to a constant mass using a drying apparatus described in T 99 to determine the moisture content. The moisture sample shall have a mass not less than 500 g.

**METHOD D**

11. SAMPLE

11.1 Select the representative sample in accordance with Section 8.3 except that it shall have a mass of approximately 25 lb (11 kg).
12. PROCEDURE

12.1 Follow the same procedure as described for Method C in Section 9, except for the following:
Form a specimen by compacting the prepared soil in the 6-in. (152.4-mm) mold (with collar
attached) in three approximately equal layers to give a total compacted depth of about 5 in.
(125 mm), each layer being compacted by 56 uniformly distributed blows from the rammer.
For molds conforming to tolerances given in T 99, and masses recorded in kilograms, multiply
the mass of the compacted specimen and the mold, minus the mass of the mold, by 471, and
record the result as the wet density, W₁, in kilograms per cubic meter, of compacted soil. For
molds conforming to tolerances given in T 99, and masses recorded in pounds, multiply the
mass of the compacted specimen and the mold, minus the mass of the mold, by 13.33, and
record the result as the wet density, W₁, in pounds per cubic foot, of the compacted soil. For
used molds out of tolerance by not more than 50 percent (T 99), use the factor for the mold
as determined in accordance with AASHTO T 19.

CALCULATIONS AND REPORT

13. CALCULATIONS

12.1 See T 99, Section 12.

14. MAXIMUM DENSITY AND OPTIMUM MOISTURE CONTENT DETERMINATION

14.1 The calculations in Section 12.1 shall be made to determine the moisture content and
corresponding over-dry density (mass) in pounds per cubic foot (kilograms per cubic meter)
of the compacted specimen. The dry density (unit mass) of the soil shall be plotted as ordinate
and the corresponding moisture content as the abscissa to define one-point within or on the
family of curves (Figure 1).

14.2 If the one-point falls on one of the curves in the family of curves the maximum dry density and
optimum moisture content defined by that curve shall be used (Note 4).

14.3 If the one-point falls within the family but not on a curve, a new curve shall be drawn through
the plotted one-point parallel and in character with the nearest existing curve in the family of
curves. The maximum dry density and optimum moisture content as defined by the new curve
shall be used (Note 4).

Note 4: If the one-point plotted within or on the family of curves does not fall in the 80 to
100 percent of optimum moisture range, compact another specimen, using the same material,
at an adjusted moisture content that will place the one-point within this range.

14.3.1 If the family of curves is such that the profile of a new curve to be drawn through a
one-point is not well defined or in any way questionable, then a full moisture-density
relationship shall be made for the soil in question to correctly define the new curve and
verify the applicability of the family of curves (Note 5).

Note 5: New curves drawn through plotted one-point determinations shall not become
a permanent part of the family of curves until verified by a full moisture-density
relationship.
16. REPORT

16.1 The report shall include the following:

16.1.1 The method used (Method A, B, C, or D).

16.1.2 The optimum moisture content as a percentage to the nearest whole number.

16.1.3 The maximum density to the nearest 1.0 lb/ft³ (0.5 kg/m³).

16.1.4 In Methods C and D indicate if the material retained on the 3/4-in. (19.0-mm) sieve was removed or replaced.

16.1.5 Type of face if other than 2-in. (50.8-mm) circular.

*Note 6:* Inherent variability of soils places limitations on this method of test. The person using this test method must realize this and become thoroughly familiar with the material being tested. Knowledge of the AASHTO Soil Classification System and ability to recognize the gradation of soils are requirements for this work.
APPENDIX

DEVELOPING A MOISTURE-DENSITY FAMILY OF CURVES

The purpose of the family of curves is to represent the average moisture-density characteristics of the material. The family must, therefore, be based on moisture-density relationships which adequately represent the entire mass range and all types of material for which the family is to be used. It may be that particular soil types have moisture-density relationships that differ considerably and cannot be represented on one general family of curves; in this case a separate family may be developed. Also, moisture-density relationships for material of widely varying geologic origins should be carefully examined to determine if separate families are required.

When a small number of moisture-density relationships are being used to develop a family of curves, plot the point representing the maximum density and optimum moisture content for each relationship on a single sheet of graph paper. Draw a smooth curve which as closely as possible connects all these points. This line will define the maximum density and optimum moisture content of the material represented by this family of curves. At 2-lb (1-kg) increments draw moisture-density curves with slopes similar to the slopes of the original moisture-density relationships. Slopes should gradually steepen going from low to high maximum density material.

When a great number of moisture-density relationships are available, the above procedure can be modified by using average values. Tabulate the maximum density, optimum moisture content, and slope for all moisture-density relationships in each 2-lb (1-kg) increment of density. Average the maximum densities and optimum moisture contents for each increment and plot these values. As before, draw a smooth curve which as closely as possible connects all these points. Determine the average slope for each increment, and at each 2-lb (1-kg) increment draw a moisture-density curve using this average slope value. A computer, if available, may be used to accomplish this work.

The accuracy of a family of curves can be checked by comparing the maximum density and optimum moisture content from an individual moisture-density relationship with that obtained using the One-Point Method and family of curves. A point representing 80 percent of optimum moisture content is taken from the individual moisture-density relationship and used as described in the One-Point Method to determine the maximum density and optimum moisture content from the family of curves. These values are compared with the values from the individual moisture-density relationship. The difference represents the maximum variance expected when the One-Point Method and family of curves are used for material represented by that individual moisture-density relationship. This comparison should be made for all types of material over the mass range of the family. Based on these results some adjustments may be necessary to the family and/or it may be recognized that the family is not applicable to some types of material. Families based on relatively few moisture-density relationships will generally require the closest scrutiny since it can be expected that a larger number of relationships will give better average conditions.
# Performance Exam Checklist

## Family of Curves — One-point Method

### FOP for AASHTO T 272

<table>
<thead>
<tr>
<th>Procedure Element</th>
<th>Yes</th>
<th>No</th>
</tr>
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<tbody>
<tr>
<td>1. The tester has a copy of the current procedure on hand?</td>
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<td></td>
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<tr>
<td>2. One-point determination of dry density and corresponding moisture content made in accordance with the FOP for AASHTO T 99, or AASHTO T 180?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Correct size mold used?</td>
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<tr>
<td>b. Correct number of blows per layer used (25 or 56)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Correct number of layers used (3, 4, or 5)?</td>
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<td></td>
</tr>
<tr>
<td>d. Moisture content determined in accordance with FOP for AASHTO T255/T265 or AASHTO T 217?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. One-point plotted on family of curves supplied?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. One-point falls within 80 to 100 percent of optimum moisture content in order to be valid?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. If one-point does not fall within 80 to 100 percent of optimum moisture content, another one-point determination with an adjusted water content is made?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Maximum dry density and corresponding optimum moisture content correctly estimated?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

First attempt: Pass ☐ Fail ☐  
Second attempt: Pass ☐ Fail ☐

Signature of Examiner __________________________________________

Comments:

________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
WSDOT Test Method T 716

Method of Random Sampling for Locations of Testing and Sampling Sites

1. SCOPE
   a. This method outlines the procedure for selecting sampling and testing sites in accordance with accepted random sampling techniques. It is intended that all testing and sampling locations be selected in an unbiased manner based entirely on chance.
   b. Testing and sampling locations and procedures are as important as testing. For test results or measurements to be meaningful, it is necessary that the sampling locations be selected at random, typically by use of a table of random numbers. Other techniques yielding a system of randomly selected locations are also acceptable.
   c. This procedure is divided into several sections:
      • Applications for Hot Mixture Asphalt Density and Challenge Cores, Section 5
      • Applications for Hot Mixture Asphalt (HMA) Sampling, Section 6
      • Applications for Portland Cement Concrete, Section 7
      • Applications for Aggregate and other materials, Section 8

2. Straight Random Sampling vs. Stratified Random Sampling:
   Straight random sampling considers an entire lot as a single unit and determines each sample location based on the entire lot size. Stratified random sampling divides the lot into a specified number of sublots or units and then determines each sample location within a distinct sublot. Both methods result in random distribution of samples to be tested for compliance with the agency’s specification.

3. PROCEDURE
   a. Determine the lot, or sublot size and number of tests per LOT or sublot.
   b. Determine the “X” and/or “Y” random number by using values from the random number table.
   c. Multiply the lot or sublot size by the random number. This will give you the approximate test location within the lot or sublot to do the testing.

4. Stratified Random Sampling
   a. Following determination of the LOT length in Example 1, determine the length increment for individual sublots by dividing by the number of such desired sublots. In the case of Hot Mix Asphalt Pavement this would be five sublots
   b. Determine random location factors “X” and/or “Y” values by random entry to the table.
   c. To determine the location of test No. 1 in sublot No. 1 multiply the sublot increment by the selected “X” or “Y” factor from the Random Number table, then add this amount to the beginning location. Test locations within each of the subsequent sublots are determined by calculating the fractional location within the sublot interval then adding the increment of the preceding sublot.
   d. For irregular lot or sublot sizes at the end of production, determine the location by dividing the final increment into 5 equal parts and define a test location within each.
5. APPLICATIONS FOR HOT MIX ASPHALT DENSITY AND CHALLENGE CORES  
(ENGLISH UNITS)

Note: For metric projects refer to Appendix A.

a. Determine the LOT size and number of tests per LOT. The Standard specifications set the size of a density test lot for Hot Mix Asphalt Pavement to no greater than a single day’s production or 400 tons, whichever is less, and require five tests per LOT. At the end of a day's production the final lot may be increased to a maximum of 600 tons.

b. Convert this LOT size to an area segment of the roadway based on the roadway section and depth being constructed for the course being tested. The calculations in Example 1 show how this is performed. Table 1 has been provided to give you recommend lot lengths for standard lane widths at various depths. Lot length needs to be determined to the nearest 100 feet.

Example 1  
Sample Computation for Lot Length

Using nominal compacted density of 2.05 tons/cy, and a 400 ton lot:

\[
\text{Tons per linear foot} = (1.0 \text{ ft} \times \text{width (feet)} \times \text{depth (feet)}) \times 2.05 \text{ Tons/cy} \\
\]

\[
\text{Tons per linear Foot} = \frac{1.0 \text{ ft} \times 12 \text{ ft} \times 0.15 \text{ ft} \times 2.05 \text{ tons}}{27} = 0.137 \text{ Tons per linear Foot.} \\
\]

\[
\text{Lot length} = \frac{400 \text{ Tons}}{0.137 \text{ Tons per linear Foot}} = 2900 \text{ linear Feet} \\
\]

Table 1: 
Hot Mix Asphalt Density Test Lot Length  
400 Ton lot at 2.05 tons/cubic yard

<table>
<thead>
<tr>
<th>Lane Width</th>
<th>Compacted Depth</th>
<th>Computed Lot Length</th>
<th>Recommended Lot Length</th>
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<td>1754</td>
<td>1800</td>
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<td>11 feet</td>
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</table>

LOT length may also be determined based on Nominal Designated LOT sizes. To utilize this concept, compacted mix volumes equivalent to the designated mix quantity per LOT have been determined using the nominal compacted unit weight of Hot Mix asphalt. These volumes are then converted into Density LOT lengths using the typical lane width and specified compacted depth. The included tables present the values for LOT Lengths based on English units.

c. Determine the locations of the test (or sampling) sites by using values from the random number table (Table 2) to determine the coordinate location on the roadway. In the table, use the “X” values as decimal fractions of the total length of the lot; use the “Y” values as fractions of the width, customarily measured from the right edge of the pavement. The values in the table have been set so that no measurements are taken within 1.5 LF (0.45 m) of the edge of the pavement. Whenever a test location is determined to fall within such an area (i.e., bridge end, track crossing, or night joint) the test location should be moved ahead or back on stationing, as appropriate, by 25 LF (8 m).
Table 2
Random Numbers with X and Y values

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</table>
d. In order to determine which “X” and “Y” values should be used, enter the table on a line chosen by chance. Recommended procedure is selection of a line based on the last two digits from the most recent standard count on the nuclear density gage. Subsequent “X” and “Y” values are then taken from the lines that follow. Based on the specified sampling frequency, 20 lots can be accommodated by one cycle through the table. Start each shift with a set of values determined by chance in order to obtain random selection.

e. Example 2 shows the calculations for determining the testing location for asphalt pavement density. No Figure 1

Example 2
Test Location Within the LOT
for Hot Mix Asphalt Density

For the lot: (12 ft. wide, 0.15 ft. deep, starting at station 168 + 75 with paving progressing ahead on station), Lot length was previously determined as 2,900 LF. Using the last two digits of the standard count, as in the example, 2951, assume “X” and “Y” values from line (51) in table 2: X = 0.762, Y = 0.65.

For the first test:
Beginning station: 168 + 75
Sublot length increment: 580 * 0.762 = 442
Width offset: 12 * 0.65 = 7.8 ft. (from right edge)
Location is: station: (168+75) + 442 = 173 + 17, 7.8 ft. from right edge

For the Second test:
Beginning station: (168 + 75) + (580) = 174 + 55
Sublot length increment: 580 * 0.285 = 165
Width offset: 12 * 0.28 = 3.4 ft. (from right edge)
Location is: station: (174 + 55) + 165 = (176 + 20), 3.4 ft. from right edge

For the Third test:
Beginning station: (168 + 75) + 580 + 580 = 180 + 35
Sublot length increment: 580 * 0.347 = 201
Width offset: 12 * 0.87 = 10.4 ft. (from right edge)
Location is: station: (180 + 35) + 201 = (182 + 36), 10.4 ft. from right edge

6. APPLICATIONS FOR HOT MIX ASPHALT (HMA) PAVEMENT MIXTURE

a. Determine the sublot size. The Standard Specifications define a lot as the total quantity of material or work produced for each job mix formula (JMF). The sublot size for HMA gradation, binder content, and /or volumetrics is a maximum of 800 tons, and shall be determined to the nearest 100 tons. At the end of production, the final sublot may be increased to a maximum of 2 times the sublot quantity calculated.

Sampling of binder shall be every other mixture sample.
b. Determine the locations of the test (or sampling) sites as defined in Section 3 using random numbers from Table 3, or from another Random Number Generator. Do not sample from the first or last 25 tons. Once the two-digit number is selected the corresponding four-digit number becomes the factor for determining the selection of the next sample. Random sample tonnage may be adjusted per sublot to accommodate field testing. Adjustments to random sample tonnage should be documented.

<table>
<thead>
<tr>
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<th>X</th>
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<tr>
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<td>0.834</td>
<td>0.060</td>
<td>0.011</td>
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</tr>
</tbody>
</table>

c. In order to determine which random values should be used, enter the table on a line chosen by chance. Recommended procedure is selection of a line based on the last two digits of the ignition furnace calibration.

d. Example 3 shows the calculations for determining the testing location for HMA WSDOT Form DOT 350-160 will calculate the testing location for you.
Example 3
Test Location for a Sublot of HMA

The Ignition Furnace calibration is 0.45%. Use 45 as the starting point to enter the random number table 3. The starting random number is 0.604.

**For the First test point:**

- Beginning tonnage: 0
- Sublot increment: \(800 \times 0.604 = 483\)
- Testing tonnage is at: 483 tons

**For the Second test point:**

- Beginning tonnage: 800
- Sublot increment: \(800 \times 0.087 = 70\)
- Testing tonnage is at: \(800 + 70 = 870\) tons

**For the Third test point:**

- Beginning Tonnage: \(800 + 800 = 1600\)
- Sublot increment: \(800 \times 0.334 = 267\)
- Testing tonnage is at: \(1600 + 267 = 1867\) tons

**For the Fourth test point:**

- Beginning Tonnage: \(1600 + 800 = 2400\)
- Sublot increment: \(800 \times 0.189 = 151\)
- Testing tonnage is at: \(2400 + 151 = 2551\) tons

7. **APPLICATIONS FOR PORTLAND CEMENT CONCRETE**

   a. Determine the sublot size. The Standard Specifications states after two successive tests indicate that the concrete is within specified limits; the sampling and testing frequency may decrease to one for every five truck load. Concrete samples other than initial load samples or samples for questioned acceptance will be taken from each sublot by a random selection. Random selection will be accomplished by using the random number table 3. For each day of concrete delivery and placement a new random number will be selected and the process repeated.

   b. Determine the locations of the test (or sampling) sites as defined in Section 3 using random numbers from table 3, or from another Random Number Generator. Do not sample concrete from the first \(\frac{1}{2}\) cubic yard of the truck.

   c. In order to determine which random values should be used, enter the table on a line chosen by chance. As a suggestion, select a line corresponding to the last two numbers on the first civilian license plate you see or other acceptable random means. Subsequent “X” values for following sublots on the same day are taken from the lines, which follow. Start each day with an “X” value determined by chance in order to obtain a random selection.

   d. Example 4 shows the calculations for determining the testing location for Portland Cement Concrete.
Example 4
Test Location for a Sublot of Portland Cement Concrete

For this example the random number selected is “37.” Enter the random number table 3 at (37) and the corresponding four-digit number is 0.829, this is the factor.

Based on the delivery of 10 cubic yard loads to the project. This would be adjusted by the quantity of concrete actually being delivered per load.

Next five trucks loads => 10 CY x 5 = 50 CY

50 CY x 0.829 = 41 CY to be sampled

20 CY (first two trucks) + 41 CY = sample at the 61 CY point

Therefore, the sample will be taken from the truck containing the 61st CY. (This would be samples from the first 1/3 of the truck) After approximately ½ CY of concrete has been discharged the sample should be taken. This is actually the seventh truckload delivered to the project this day as the first two truckloads were sampled before the random selection process started.

The next sample would be taken at random number “38.” Enter the random number table 3 at (39) and the corresponding four-digit number is 0.998, this is the factor.

Based on the delivery of 10 cubic yard loads to the project. This would be adjusted by the quantity of concrete actually being delivered per load.

Next five trucks loads => 10 CY x 5 = 50 CY

50 CY x 0.998 = 50 CY to be sampled

20 CY (first two trucks) 50 CY (from first random test) + 50 CY = sample at the 120 CY point . (This would be samples from the last 1/3 of the truck)

The next sample would be taken at random number “39.” Enter the random number table 3 at (38) and the corresponding four-digit number is 0.539, this is the factor.

Based on the delivery of 10 cubic yard loads to the project. This would be adjusted by the quantity of concrete actually being delivered per load.

Next five trucks loads => 10 CY x 5 = 50 CY

50 CY x 0.539 = 27 CY to be sampled

20 CY (first two trucks) 50 CY (from first random test) + (50 CY from second random test) + 27 CY = sample at the 147 CY point. (This would be samples from the middle to last 1/3 of the truck)
8. APPLICATIONS FOR AGGREGATE AND OTHER MATERIALS
   a. Determine the lot or sublot size according to the contract documents. The lot or sublot shall be determined to the nearest 100 tons.
   b. Determine the locations of the test (or sampling) sites as defined in Section 3 using random numbers from table 3, or from another Random Number Generator.
   c. In order to determine which random values should be used, enter the table on a line chosen by chance. The first two or last two digits of the next automobile license plate you see is one way to select the entry point. Another way is to start a digital stopwatch and stop it several seconds later, using the decimal part of the seconds as your entry point.

**Sampling from a Belt or Flowing Stream:** Example: The specification calls for one sample from every 1000 Tons of aggregate. If the random number is 0.371, the sample would be taken at (0.371) (1000 Tons) = 371 Tons.

**Sampling from Haul Units:** Example: The specification calls for the samples to be based on a number of haul units. Determine the number of hauling units that comprise a lot. Multiply the selected random number(s) by the number of units to determine which unit(s) will be sampled.

If 20 haul units comprise a lot and one sample is needed, using the random number 0.773, the sample would be taken from the (0.773) (20) = 15.46, or 15th haul unit.

**Sampling from a Roadway with Previously Placed Material:** Example: The specification calls for a sample from a location on a job. The process as defined in Section 5, Applications for Asphalt Paving Density should be used where a X and Y measurement is needed to determine the testing location.
Appendix A  APPLICATIONS FOR HOT MIX ASPHALT DENSITY AND CHALLENGE CORES (metric Units)

a. Determine the LOT size and number of tests per LOT. The Standard specifications set the size of a density test lot for Asphalt Pavement to no greater than a single day’s production or approximately 400 tonne, whichever is less, and require five tests per LOT. At the end of a day’s production and the final lot is greater than 400 tonne, it should be broken up into two lots.

b. Convert this LOT size to an area segment of the roadway based on the roadway section and depth being constructed for the course being tested. The calculations in Example 1 show how this is performed. Table 1 has been provided to give you recommend lot lengths for standard lane widths at various depths. Lot length needs to be determined to the nearest 30 meters.

Example 1

Sample Computation for Lot Length (Metric Units)

Using nominal compacted density of 2 439 kg/m$^3$, compacted depth of 40 mm and paving width of 3.6 m:

Lot Length:

400 tonnes equate to 400 000 kg

Cross-section pavement area: 3.6 m wide, 0.040 m (40 mm) deep = 0.144 m$^2$

Unit weight per meter length = 0.144 m$^2$ * 2439 kg/m$^3$ = 351.2 kg/m

Length = 400 000 kg/351.2 kg/m = 1138.9 m round to 1140 m

Sublot length = 1140 m * 0.2 = 228 m

These typical figures may be revised based on the actual densities achieved or the yield results from the paving involved.

Table 1: Hot Mix Asphalt Density Test Lot Sizes Metric Units

<table>
<thead>
<tr>
<th>Lane Width</th>
<th>Compacted Depth</th>
<th>Computed Lot Length</th>
<th>Recommended Lot Length</th>
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</thead>
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<td>1139</td>
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<td>75 mm</td>
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<td>660</td>
</tr>
</tbody>
</table>

LOT length may also be determined based on Nominal Designated LOT sizes. To utilize this concept, compacted mix volumes equivalent to the designated mix quantity per LOT have been determined using the nominal compacted unit weight of Hot Mix Asphalt pavement. These volumes are then converted into Density LOT lengths using the typical lane width and specified compacted depth. The included tables present the values for LOT Lengths based on English units.
c. Determine the locations of the test (or sampling) sites by using values from the random number table (Table 2) to determine the coordinate location on the roadway. In the table, use the “X” values as decimal fractions of the total length of the lot; use the “Y” values as fractions of the width, customarily measured from the right edge of the pavement. The values in the table have been set so that no measurements are taken within 1.5 LF (0.45 m) of the edge of the pavement. Whenever a test location is determined to fall within such an area (i.e., bridge end, track crossing, or night joint) the test location should be moved ahead or back on stationing, as appropriate, by 25 LF (8 m).

d. In order to determine which “X” and “Y” values should be used, enter the table on a line chosen by chance. Recommended procedure is selection of a line based on the last two digits from the most recent standard count on the nuclear density gage. Subsequent “X” and “Y” values are then taken from the lines that follow. Based on the specified sampling frequency, 20 lots can be accommodated by one cycle through the table. Start each shift with a set of values determined by chance in order to obtain random selection.

e. Example 2 shows the calculations for determining the testing location for asphalt pavement density.

Example 2
Test Location Within the LOT
for Hot Mix Asphalt Pavement Density (Metric Units)

For the lot defined above (3.6 m wide, 1140 m long) starting at station 10 000.00 m

Using the last two digits of the standard count. Determine the “X” and “Y” values from line (51) in the table: X = 0.762, Y = 0.65 (these are illustrative examples only. Table format and generation have been randomized so that each replication of the table will vary).

Beginning station: 10 000.00
Sublot length increment: 228 * 0.762 = 173.7 m
Width offset: 3.6 * 0.65 = 2.3 m (from right edge)
Location is station: 10 000 + 173.7 = 10 173.7, 2.2 m from right edge
Correlation of Nuclear Gauge Densities with Hot Mix Asphalt (HMA) Cores

1. Gauge-core correlation shall be required for statistical evaluation of degree of asphalt compaction.
   a. For each combination of gauge and initial job mix formula.
   b. For direct transmission and for back scatter modes (when used).
   c. For a change in the class of HMA.

2. A new gauge correlation is not required.
   a. For different contracts if JMF and gauge are the same.
   b. For a change in bases (i.e., surfacing to overlay).
   c. When the job mix formula has been adjusted in accordance with Section 9-03.8(6)A of the *Standard Specifications*.

3. Gauge correlation is based on 10 density determinations and 10 cores taken at corresponding locations. Gauge densities shall be determined in accordance with WSDOT FOP for WAQTC TM 8. Cores should be taken no later than the day following paving and before traffic has been allowed on roadway. The sites for correlation cores do not have to be record density core sites and therefore consideration should be given to selecting sites out of the travel way.

   *Note1:* If a core becomes damaged, it may be eliminated from the average.

   *Note2:* Cores may be taken sooner than the day after paving by cooling the pavement to allow for hardening of the HMA to prevent damage to the core when taking the sample. Water, ice, or even dry-ice would be expedient means to cool the pavement. Nitrogen gas or CO2 uses as replacement drilling fluids may also be involved.

4. Obtain a pavement core from each of the test sites in accordance with WSDOT SOP 734. The core shall be taken in between the two nuclear gauge footprints. If direct transmission was used, locate the core at least 1 in. (25 mm) away from the edge of the drive pin hole.

5. Core densities shall be determined in conformance with AASHTO T 166 Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens.

6. Correlation factor shall be determined to 0.001 using Standard Form 350-112: Correlation Nuclear Gauge to Core Density, or other comparable forms.
1. **Scope**

   1.1 This test method covers the determination of a rebound number of hardened concrete using a spring-driven steel hammer.

   1.2 The values stated in **inch-pound** units are to be regarded as 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:*

       C 125  Terminology Relating to Concrete and Concrete Aggregates
       C 670  Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
       E 18  Test Methods for Rockwell and Rockwell Superficial Hardness of Metallic Materials

3. **Terminology**

   3.1—**Definitions:**

       3.1.1 For definitions of terms used in this test method, refer to Terminology C 125.

4. **Summary of Test Method**

   4.1 A steel hammer impacts, with a predetermined amount of energy, a steel plunger in contact with a surface of concrete, and the distance that the hammer rebounds is measured.

5. **Significance and Use**

   5.1 This test method is applicable to assess the in-place uniformity of concrete, to delineate regions in a structure of poor quality or deteriorated concrete, and to estimate in-place strength development.

   5.2 To use this test method to estimate strength requires establishing a relationship between strength and rebound number. The relationship shall be established for a given concrete mixture and given apparatus. The relationship shall be established over the range of concrete strength that is of interest. To estimate strength during construction, establish the relationship by performing rebound number tests on molded specimens and measuring the strength of the same or companion molded specimens. To estimate strength in an existing structure, establish the relationship by correlating rebound numbers measured on the structure with the strengths of cores taken from corresponding locations. See ACI 228.1R-4 for additional information on developing the relationship and on using the relationship to estimate in-place strength.

   5.3 For a given concrete mixture, the rebound number is affected by factors such as moisture content of the test surface, the method used to obtain the test surface (type of form material or type of finishing), and the depth of carbonation. These factors need to be considered in preparing the strength relationship and interpreting test results.
5.4 Different hammers of the same nominal design may give rebound numbers differing from 1 to 3 units. Therefore, tests should be made with the same hammer in order to compare results. If more than one hammer is to be used, perform tests on a range of typical concrete surfaces so as to determine the magnitude of the differences to be expected.

5.5 This test method is not intended as the basis for acceptance or rejection of concrete because of the inherent uncertainty in the estimated strength.

6. Apparatus

6.1 Rebound Hammer, consisting of a spring-loaded steel hammer that when released strikes a steel plunger in contact with the concrete surface. The spring-loaded hammer must travel with a consistent and reproducible velocity. The rebound distance of the steel hammer from the steel plunger is measured on a linear scale attached to the frame of the instrument.

NOTE 1—Several types and sizes of rebound hammers are commercially available to accommodate testing of various sizes and types of concrete construction.

6.2 Abrasive Stone, consisting of medium-grain texture silicon carbide or equivalent material.

6.3 Test Anvil, approximately 150-mm (6-in.) diameter by 150-mm (6-in.) high cylinder made of tool steel with an impact area hardened to 66 ± 2 HRC as measured by Test Methods E 18. An instrument guide is provided to center the rebound hammer over the impact area and keep the instrument perpendicular to the surface.

6.4 Verification—Rebound hammers shall be serviced and verified annually and whenever there is reason to question their proper operation. Verify the functional operation of a rebound hammer using the test anvil described in 6.3. During verification, support the test anvil on a bare concrete floor or slab. The manufacturer shall report the rebound number to be obtained by a properly operating instrument when tested on an anvil of specified hardness.

NOTE 2—Typically, a rebound hammer will result in a rebound number of 80 ± 2 when tested on the anvil described in 6.3. The test anvil needs to be supported on a rigid base to obtain reliable rebound numbers. Verification on the test anvil does not guarantee that the hammer will yield repeatable data at other points on the scale. The hammer can be verified at lower rebound numbers by using blocks of polished stone having uniform hardness. Some users compare several hammers on concrete or stone surfaces encompassing the usual range of rebound numbers encountered in the field.

7. Test Area and Interferences

7.1 Selection of Test Surface—Concrete members to be tested shall be at least 100 mm (4 in.) thick and fixed within a structure. Smaller specimens must be rigidly supported. Avoid areas exhibiting honeycombing, scaling, or high porosity. Do not compare test results if the form material against which the concrete was placed is not similar (see Note 3). Troweled surfaces generally exhibit higher rebound numbers than screeded or formed finishes. If possible, test structural slabs from the underside to avoid finished surfaces.

7.2 Preparation of Test Surface—A test area shall be at least 150 mm (6 in.) in diameter. Heavily textured, soft, or surfaces with loose mortar shall be ground flat with the abrasive stone described in 6.2. Smooth-formed or troweled surfaces do not have to be ground prior to testing (see Note 3). Do not compare results from ground and unground surfaces.
NOTE 3—Where formed surfaces were ground, increases in rebound number of 2.1 for plywood formed surfaces and 0.4 for high-density plywood formed surfaces have been noted.5 Dry concrete surfaces give higher rebound numbers than wet surfaces. The presence of surface carbonation can also result in higher rebound numbers.6 The effects of drying and surface carbonation can be reduced by thoroughly wetting the surface for 24 h prior to testing. In cases of a thick layer of carbonated concrete, it may be necessary to remove the carbonated layer in the test area, using a power grinder, to obtain rebound numbers that are representative of the interior concrete. Data are not available on the relationship between rebound number and thickness of carbonated concrete. The user must exercise professional judgment when testing carbonated concrete.

7.3 Do not test frozen concrete.

NOTE 4—Moist concrete at 0 °C (32 °F) or less may exhibit high rebound values. Concrete should be tested only after it has thawed. The temperatures of the rebound hammer itself may affect the rebound number. Rebound hammers at -18 °C (0 °F) may exhibit rebound numbers reduced by as much as 2 or 37.

7.4 For readings to be compared, the direction of impact, horizontal, downward, upward, or at another angle, must be the same or established correction factors shall be applied to the readings.

7.5 Do not conduct tests directly over reinforcing bars with cover less than 0.75 in. [20 mm].

NOTE 5—The location of reinforcement may be established using reinforcement locators or metal detectors. Follow the manufacturer’s instructions for proper operation of such devices.

8. Procedure

8.1 Hold the instrument firmly so that the plunger is perpendicular to the test surface. Gradually push the instrument toward the test surface until the hammer impacts. After impact, maintain pressure on the instrument and, if necessary, depress the button on the side of the instrument to lock the plunger in its retracted position. Read the rebound number on the scale to the nearest whole number and record the rebound number. Take ten readings from each test area. No two impact tests shall be closer together than 25 mm (1 in.). Examine the impression made on the surface after impact, and if the impact crushes or breaks through a near-surface air void disregard the reading and take another reading.

9. Calculation

9.1 Discard readings differing from the average of 10 readings by more than 6 units and determine the average of the remaining readings. If more than 2 readings differ from the average by 6 units, discard the entire set of readings and determine rebound numbers at 10 new locations within the test area.
10. Report

10.1 Report the following information for each test area:

10.1.1 Date and time of testing.

10.1.2 Identification of location tested in the concrete construction and the type and size of member tested,

10.1.2.1 Description of the concrete mixture proportions including type of coarse aggregates if known, and

10.1.2.2 Design strength of concrete tested.

10.1.3 Description of the test area including:

10.1.3.1 Surface characteristics (trowelled, screeded) of area,

10.1.3.2 If surface was ground and depth of grinding, 5 Gaynor, R. D., “In-Place Strength of Concrete—A Comparison of

10.1.3.3 Type of form material used for test area,

10.1.3.4 Curing conditions of test area,

10.1.3.5 Type of exposure to the environment,

10.1.4 Hammer identification and serial number,

10.1.4.1 Air temperature at the time of testing,

10.1.4.2 Orientation of hammer during test,

10.1.5 Average rebound number for test area, and

10.1.5.1 Remarks regarding discarded readings of test data or any unusual conditions.

11. Precision and Bias

See ASTM C 805 Precision and Bias

11.1 Precision—The single-specimen, single-operator, machine, day standard deviation is 2.5 units (1σ) as defined in Practice C 670. Therefore, the range of ten readings should not exceed 12.

11.2 Bias—The bias of this test method cannot be evaluated since the rebound number can only be determined in terms of this test method.

12. Keywords

12.1 concrete; in-place strength; nondestructive testing; rebound hammer; rebound number
Performance Exam Checklist

Rebound Hammer Determination of Compressive Strength of Hardened Concrete
FOP For ASTM C 805

Participant Name __________________________________________ Exam Date ______________

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</tr>
</thead>
<tbody>
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<td></td>
<td></td>
</tr>
<tr>
<td>2. Hammer properly serviced and calibrated or verified?</td>
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<tr>
<td>3. Test location properly prepared?</td>
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<tr>
<td>4. Test location meets minimum size requirement?</td>
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<td>5. Ten acceptable readings taken in each test area?</td>
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<td>6. Readings properly spaced in test area?</td>
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<td>7. Test readings properly converted to estimated strength?</td>
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</tr>
<tr>
<td>8. Test information properly recorded?</td>
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<tr>
<td>9. All calculations performed correctly?</td>
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</table>

Equipment

10. Where required are calibration/verifications tags present on equipment used in this procedure? |     |    |
11. All equipment functions according to the requirements of this procedure?         |     |    |

First attempt:  Pass ☐  Fail ☐  Second attempt:  Pass ☐  Fail ☐

Signature of Examiner __________________________________________

Comments:

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________________________________________________________________________
WSDOT Test Method for ASTM C 939¹

Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)

This standard is issued under the fixed designation C 939; 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 (e) indicates an editorial change since the last revision or reapproval. This specification has been approved for use by agencies of the Department of Defense.

1. SCOPE

1.1 This test method covers a procedure, used both in the laboratory and in the field, for determining the time of efflux of a specified volume of fluid hydraulic cement grout through a standardized flow cone and used for preplaced-aggregate (PA) concrete; however, the test method may also be used for other fluid grouts.

1.2 It is for use with neat grout and with grouts containing fine aggregate all passing a No. 8 (2.36-mm) sieve.

1.3 This test method is intended for use with grout having an efflux time of 35 s or less.

1.4 When efflux time exceeds 35 s, flowability is better determined by flow table, found in Test Method C 109, using 5 drops in 3 s.

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

1.6 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:

   (Using 2-in. or 50-mm Cube Specimens)

   C 938 Practice for Proportioning Grout Mixtures for Preplaced-Aggregate Concrete

3. SUMMARY OF TEST METHOD

3.1 The time of efflux of a specified volume of grout from a standardized flow cone is measured.

4. SIGNIFICANCE AND USE

4.1 This test method is applicable to the determination of the fluidity of various fluid grout mixtures.

5. INTERFERENCES

5.1 The presence of solid particles retained on the No. 8 (2.36-mm) sieve or lumps of unmixed material in the grout may cause the grout to flow unevenly through the discharge tube of the flow cone or stop the flow completely. Uneven flow will result in slower transit of the grout, thereby indicating a false consistency.

¹This Test Method is based on ASTM C 939-97.
6. APPARATUS

6.1 *Flow Cone,* with dimensions as shown in Figure 1. The discharge tube shall be stainless steel. The body can be stainless steel, cast aluminum, or other essentially noncorroding metal.

*Note 1:* Cones with high-density polyethylene bodies are acceptable for field use in situations where precision as described in this test method is not required.

6.2 *Receiving Container,* capacity 2000 mL, minimum.

6.3 *Ring Stand* or other device, capable of supporting the flow cone in a vertical, steady position over the receiving container.

6.4 *Level,* carpenter’s or similar.

6.5 *Stop Watch,* least reading of not more than 0.2 s.

6.6 *Grout Mixer,* conforming to Practice C 938.

7. TEST SAMPLE

7.1 The grout test sample shall be in excess of 1725 mL and shall be representative of the grout in the mixer.

7.2 When sampling and testing is being done for the purpose of proportioning or comparing mixes or for qualifying materials, the temperature of the dry materials and mixing water shall be such that the temperature of the freshly mixed grout is 73.4 ± 3°F (23 ± 1.7°C), unless otherwise specified.

8. CALIBRATION OF APPARATUS

8.1 Mount the flow cone firmly in such a manner that it is free of vibration. Level the top to assure verticality. Close the outlet of the discharge tube with a finger or a stopper. Introduce 1725 ± 5 mL of water into the cone. Adjust the point gage to indicate the level of the water surface. Then allow the water to drain.

8.2 Before first use of the flow cone with grout and periodically thereafter, check the accuracy of the cone by filling it with water as described in 8.1. After checking or adjusting the point gage, start the stop watch and simultaneously remove the finger. Stop the watch at the first break in the continuous flow of water. The time indicated by the stop watch is the time of efflux of water. If this time is 8.0 ± 0.2 s, the cone may be used for determining the time of efflux of grout.

*Note:* It is imperative that the water be completely still prior to allowing it to flow from the cone, any movement will cause the time of efflux to increase.

9. PROCEDURE

9.1 Moisten the inside of the flow cone by filling the cone with water and, 1 min before introducing the grout sample, allow the water to drain from the cone. Close the outlet of the discharge tube with a finger or a stopper. Introduce the grout into the cone until the grout surface rises to contact the point gage, start the stop watch, and simultaneously remove the finger or stopper. Stop the watch at the first break in the continuous flow of grout from the discharge tube, then look into the top of the cone; if the grout has passed sufficiently, such that light is visible through the discharge tube, the time indicated by the stop watch is the time of efflux of the grout. If light is not visible through the discharge tube, then the use of the flow cone is not applicable for grout of this consistency. At least two tests having times of efflux within 1.8 s of their average shall be made for each grout mixture.
9.2 The test for time of efflux shall be made within 1 min of drawing of the grout from the mixer or transmission line. When grout is being placed over a significant period of time, the time of efflux may be determined at selected intervals to demonstrate that the consistency is suitable for the work.

10. REPORT

10.1 Report the following information:

10.1.1 Identification of sample,

10.1.2 Identification of materials in the sample, the proportions, and whether laboratory prepared or taken from the field production mix,

10.1.3 Average time of efflux to nearest 0.2 s and time interval from completion of mixing at which the test was made, and

Note 2: Other means of indicating grout level may be used as long as accurate indication of grout level on volume is obtained.

10.1.4 Temperature, ambient and of the sample at the time of test.

11. PRECISION AND BIAS

11.1 Precision — The following within-laboratory, multiple-operator precision applies. The single laboratory standard deviation has been found to be 0.88 s. Therefore, results from two properly conducted tests on the same material should not differ by more than 2.49 s.

11.2 Bias — No statement on bias can be prepared because there are no standard reference materials.

12. KEYWORDS

12.1 flow cone; grout; preplaced—aggregate concrete; time of efflux
# Performance Exam Checklist

**Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)**

**FOP FOR ASTM C 939**

<table>
<thead>
<tr>
<th>Participant Name</th>
<th>Exam Date</th>
</tr>
</thead>
</table>

<p>| Procedure Element                                                                 | Yes | No |
|------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. The tester has a copy of the current procedure on hand?                                                                                      | ☐   | ☐ |
| 2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?       | ☐   | ☐ |
| 3. Is the grout that is being tested a “fluid grout?”                                                                                         | ☐   | ☐ |
| 4. Will the grout pass through a No. 8 (2.36 mm) sieve?                                                                                      | ☐   | ☐ |
| 5. Is the cone set level and vibration free?                                                                                                 | ☐   | ☐ |
| 6. Is the grout test sample in excess of 1.8 quarts and representative of the grout being produced?                                            | ☐   | ☐ |
| 7. Is the grout being produced at the specified temperature (73.4 ± 3 F)?                                                                     | ☐   | ☐ |
| 8. Does the tester have a verified stopwatch capable measuring to a time of 0.2 sec.?                                                        | ☐   | ☐ |
| 9. Was the water calibration performed prior to use and is there a record of the previous calibrations for this cone?                        | ☐   | ☐ |
| 10. Was adjustment of the level indicator required?                                                                                          | ☐   | ☐ |
|                                                                 Note: The calibration with water of a volume of 1725 mL ± 5 mL is to be 8 seconds ± 0.2 seconds to be considered valid for acceptance.   | ☐   | ☐ |
| 11. Was the cone filled with water a minute prior to introducing grout?                                                                     | ☐   | ☐ |
| 12. Water drained and cone outlet closed with a stopper/finger then grout introduced into the cone until the grout surface rises to contact the point gauge? | ☐   | ☐ |
| 13. Stopwatch started as stopper/finger is removed and then stopped and then stopped at the first break in continuous flow is observed?     | ☐   | ☐ |
| 14. Immediately observe to see if discharge tube is clear and light is visible through it?                                                    | ☐   | ☐ |
| 15. Repeat procedure and determine if the second observed flow rate is within 1.8 s of the average of the two flow rates.                  | ☐   | ☐ |</p>
<table>
<thead>
<tr>
<th>Procedure Element</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>16. Record the average time of efflux to the nearest 0.2 seconds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. All calculations performed correctly?</td>
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<tr>
<td>First attempt: Pass ☐ Fail ☐</td>
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<td></td>
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<tr>
<td>Second attempt: Pass ☐ Fail ☐</td>
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Signature of Examiner __________________________________________

Comments:
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Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base

1. SCOPE

1.1 These test methods cover the nondestructive measurement of the dry film thickness of nonmagnetic coatings applied over a ferrous base material using commercially available test instruments. The test methods are intended to supplement manufacturers’ instructions for the manual operation of the gages and are not intended to replace them. They cover the use of instruments based on magnetic measuring principles only. Test Method A provides for the measurement of films using mechanical magnetic pull-off gages and Test Method B provides for the measurement of films using magnetic electronic gages.

1.2 These test methods are not applicable to coatings that will be readily deformable under the load of the measuring instruments, as the instrument probe must be placed directly on the coating surface to take a reading.

1.3 The values given in SI units of measurement are to be regarded as the standard. The values in parentheses are for information only.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. REFERENCED DOCUMENTS

2.1 ASTM Standards:
   D 609 Practice for Preparation of Cold-Rolled Steel Panels for Testing Paint, Varnish, Conversion Coatings, and Related Coating Products
   D 823 Practices for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels

2.2 Steel Structures Painting Council Standard:
   SSPC-PA2 Measurement of Dry Paint Thickness with Magnetic Gages

TEST METHOD A—MAGNETIC PULL-OFF GAGES

3. SUMMARY OF TEST METHOD

3.1 Instruments complying with this test method measure thickness by using a spring calibrated to determine the force required to pull a magnet from a ferrous base coated with a nonmagnetic film. The instrument must be placed directly on the coating surface to take a reading.

3.2 The attractive force of the magnet to the substrate varies inversely with the thickness of the applied film. The spring tension required to overcome the attraction of the magnet to the substrate is shown on the instrument scale as the distance (in mils or microns) between the magnet and the substrate.

4. SIGNIFICANCE AND USE

4.1 Many coating properties are markedly affected by the thickness of the dry film such as adhesion, corrosion protection, flexibility, and hardness. To be able to compare results obtained by different operators, it is essential to know film thickness.

1 This FOP is based on ASTM D 1186-01
4.2 Most protective and high performance coatings are applied to meet a requirement or a specification for the dry-film thickness of each coat, or for the complete system, or both. Coatings must be applied within certain minimum and maximum thicknesses to fill their expected function. In addition to potential performance deficiencies, it is uneconomical to apply more material than necessary when coating large areas. This test method is used to measure film thickness of coatings on ferrous metals.

5. APPARATUS

5.1 *Permanent Magnet*, small, either attached directly to a coil spring (“pencil” gage) or to a horizontal lever arm that is attached to a helical spring (“dial-type” gage). Increasing force is applied to the magnet by extending the coil spring in the first case or turning a graduated dial that coils the helical spring in the second. The readings obtained are shown directly on the instrument scale.

5.2 *Coating Thickness Standards*, with assigned values traceable to national standards are available from several sources, including most manufacturers of coating thickness gages.

6. TEST SPECIMENS

6.1 When this test method is used in the field, the specimen is the coated structure or article on which the thickness is to be evaluated.

6.2 For laboratory use, apply the material to be tested to panels of similar roughness, shape, thickness, composition and magnetic properties on which it is desired to determine the thickness.

NOTE 1—Applicable test panel description and surface preparation methods are given in Practice D 609.

NOTE 2—Coatings should be applied in accordance with Practices D 823 or as agreed upon between the contracting parties.

7. VERIFICATION OF CALIBRATION OF APPARATUS

7.1 Different gage manufacturers follow different methods of calibration adjustment. Verify calibration according to manufacturer’s instructions.

7.2 The section of the type of standards used to verify calibration should be predicated upon which type provides the best and most appropriate calibration considering: type of gage, sample surface geometry, and contract requirements. Appendix X1 provides information helpful to making an informed selection of standards.

7.3 Following the manufacturer’s operating instructions, measure the thickness of a series of calibration standards covering the expected range of coating thickness. To guard against measuring with an inaccurate gage, recheck the gage at regular intervals. That interval should be set by agreement between contracting parties and maintained throughout the control process.

NOTE 3—Generally “Dial-type” instruments can be used in any position, while “pencil-type” instruments may be used in the vertical position only unless they have separate indicators for the horizontal and vertical positions. Follow the manufacturer’s recommendations.

8. PROCEDURE

8.1 Use the instrument only after calibration has been verified in accordance with Section 7.

8.2 Ensure that the coating is dry prior to use of the instrument.
8.3 Inspect the probe tip and surface to be measured to ensure that they are clean. Adherent magnetic filings or other surface contaminants will affect gage readings.

8.4 Take readings in locations free of electrical or magnetic fields. The location should also be free of vibration when using mechanical magnetic pull-off instruments.

8.5 The accuracy of the measurement can be influenced when made within 25 mm (1 in.) of the edge or right angle in the sample.

8.6 Measure the coating, following the manufacturer’s instructions.

8.7 Verify calibration periodically to ensure that the instrument continues to read properly. If the instrument is found to be out of adjustment, remeasure the thicknesses taken since the last satisfactory calibration check was made.

8.8 Take a sufficient number of readings to characterize the surface.

8.8.1 For laboratory measurements, a recommended minimum is three for a 75 by 150-mm (3 by 6-in.) panel and more in proportion to size.

8.8.2 For field measurements, a recommended minimum is five determinations at random for every 10 m² (100 ft²) of surface area. Each of the five determinations should be the mean of three separate gage readings within the area of a 4-cm (1.5-in.) diameter circle.

8.9 Make measurements at least 13 mm (1/2 in.) away from any edge or corner of the specimen. If it is necessary to measure closer than 13 mm (1/2 in.), verify the effect (if any), the edge has on the measurement.

NOTE 4—For additional information describing the number of measurements to be taken on large structures, and on non-smooth surfaces, refer to SSPC PA-2.

9. REPORT

9.1 Report the following information:

9.1.1 Instrument used, serial number,

9.1.2 Range, and mean of the thickness readings, and

9.1.3 Depending upon the application, record the individual readings as well.

Report the information on the attached form.

Material represented by the test specimens when tested under this method and found to meet the specified minimum coating thickness may be accepted. Any specimens which does not meet the minimum coating thickness will not be retested using this test method.

Samples of the material will be submitted to either the Eastern Region Consolidated Materials Laboratory or the State Material laboratory for referee testing in accordance with AASHTO T 65.
Field Report of Thickness of Nonmagnetic Coating on a Ferrous Base

Contract __________________    Bid Item No ________     Item ________________________________

Specimen No. _____________________________

Specification: _______________________    Coating Thickness Required _______________ (mils),(mm)

Surface area of test specimen _____________ m² (ft²)    Test represents ______________________

Instrument Serial No. ____________________________     Calibration Date _______________________

Tested by: _________________________________________________________    Date: ___/___/20___

<table>
<thead>
<tr>
<th>Reading No.</th>
<th>Test Location</th>
<th>Reading</th>
<th>Avg Readings</th>
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<tbody>
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Average
10. PRECISION AND BIAS

10.1 A new round-robin study was performed recently. Data are being analyzed statistically. When completed, the required “Repeatability and Reproducibility” sections of this test method will be written and the round-robin study documented in an ASTM research report.

10.2 Bias—The bias for Test Method A of this standard for measuring dry film thickness cannot be determined because each instrument has its own bias.

TEST METHOD B—ELECTRONIC GAGES

11. SUMMARY OF TEST METHOD

11.1 Instruments complying with this test method measure thicknesses by placing a probe on the coated surface and use electronic circuitry to convert a reference signal into coating thickness.

11.2 Instruments of this type determine, within the probe or the instrument itself, changes in the magnitic flux caused by variations in the distance between the probe and the substrate.

12. APPARATUS

12.1 The testing apparatus shall be an electrically operated instrument utilizing a probe that houses a permanent magnet or coil energized by alternating current that is placed directly on the surface. The coating thickness is shown on the instrument’s display.

12.2 Coating thickness standards with assigned values traceable to national standards are available.

13. TEST SPECIMENS

13.1 See Section 6.

14. CALIBRATION OF APPARATUS

14.1 See Section 7.

15. PROCEDURE

15.1 See Section 8. Exclude steps 8.5 and 8.7.

16. REPORT

16.1 See Section 9.

17. PRECISION AND BIAS

17.1 Precision—See Section 10.

17.2 Bias—The bias for Test Method B of this standard for measuring dry film thickness cannot be determined because each instrument has its own bias.

18. KEYWORDS

18.1 coating thickness; dry film thickness; magnetic gages; nondestructive thickness; paint thickness

APPENDIX

X1. CHARACTERISTICS AFFECTING GAGE READINGS

X1.1 It is always good practice to ensure the reliability of gage readings by performing a verification test periodically, either before or after critical determinations. This practice ensures that, not only is the gage reading correctly, but also that it is correctly calibrated to provide maximum accuracy of readings on the sample. Not all applications require this level of certainty so, while suggested, the inclusion of this practice is up to the contacting individuals to decide on implementation.
X1.2 Certain characteristics of samples may affect the accuracy of the calibrations. These include, but may not be limited to:

X1.2.1 Surface profile of the substrate (roughness),
X1.2.2 Surface profile of the coating,
X1.2.3 Thickness of the substrate,
X1.2.4 Geography of the sample surface (curves with small radii, small diameters, complex curves, etc.), and
X1.2.5 Any characteristic that affects the magnetic or eddy current permeability of the substrate or coating, such as residual magnetism, or lack of homogeneity of magnetic characteristics.

X1.3 Calibration done on smooth, polished standards ensure that a gage can be properly calibrated, and that calibration is appropriate for any measurements on samples of the same characteristics, but it may not be the best for measurements of samples that differ from the calibration materials. When possible, verification should be done on samples of known thickness of coating applied to substrates as similar as possible to the sample to be tested.

X1.4 It is not practical to provide known thickness standards for all possible sample configurations. An alternative method is to verify calibration on a bare substrate as similar as possible to the sample, using a nonmagnetic metal foil, plastic shim or film of known thickness to simulate a coating.

X1.5 In using this verification of calibration method, it is necessary to be aware of additional characteristics that can affect the measured values. Plastic or brass shim stock typically has an inherent curve. This curve can act as a leaf spring and cause a magnetic pull-off gage to be “pushed” off the surface prematurely, resulting in an incorrect reading.

X1.6 With some materials and thickness, it is possible that the shim will not lie flat, which will also cause an erroneous reading. Various techniques exist to minimize this effect, such as mounting the shim in a holder that maintains tension on the shim to eliminate the tendency of the shim to curve.

X1.7 Other factors experienced with plastic shims, which are not usually present with painted or plated calibration standards include (but are not limited to):

X1.7.1 Permanent creases in the shim due to folding,
X1.7.2 Air entrapment between the shim and substrate,
X1.7.3 Distortion due to environmental conditions, such as temperature, and
X1.7.4 Shim thickness inconsistency due to the pressure of the probe tip. This may be a permanent “dimple” in the shim.

X1.8 Even with these factors affecting potential accuracy of plastic shims, in many applications, verification of calibration using plastic shims on the sample to be measured, can be a more appropriate (accurate) calibration than using plated or painted standards.

X1.9 No matter what standards are used, they should be periodically verified to ensure the assigned value is correct. Even metal coated on metal can wear or be damaged to an extent that readings are affected.
# Performance Exam Checklist

**Nondestructive Measurement of Thickness of Nonmagnetic Coatings on a Ferrous Base**  
**FOP For ASTM D 1186**

<table>
<thead>
<tr>
<th>Procedure Element</th>
<th>Test</th>
<th>Retest</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The tester has a copy of the current procedure on hand?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Instrument calibrated in accordance with the manufacturer’s instructions before use employing a suitable thickness standard?</td>
<td></td>
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<tr>
<td>4. Several readings taken and recorded taking into account edge and curvature effects?</td>
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<td></td>
</tr>
<tr>
<td>5. The average thickness converted to oz. ft(^2) (g/m(^2)) using appropriate conversion factor?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

First attempt: Pass ☐  Fail ☐

Second attempt: Pass ☐  Fail ☐

Signature of Examiner __________________________________________

**Comments:**

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